CHEMICAL OXIDATION PILOT TEST REPORT

PINE STREET MANUFACTURED GAS PLANT SITE
SPARTANBURG, SOUTH CAROLINA

Prepared for:

Duke Energy

Prepared by:

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amec

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Mr. Lucas Berresford
State Voluntary Clean-Up Section
Bureau of Land and Waste Management
South Carolina Department of health and Environmental Control
2600 Bull Street
Columbia, South Carolina 29201-1708

Subject: **Chemical Oxidation Pilot Test Report**
Pine Street Manufactured Gas Plant Site
Spartanburg, South Carolina

Dear Mr.Berresford:

AMEC Environment & Infrastructure, Inc. is pleased to submit, on behalf of Duke Energy, the results of the Chemical Oxidation Pilot Study for the Pine Street Manufactured Gas Plant Site located at 684 North Pine Street in Spartanburg, South Carolina.

If you have any questions or require further information regarding this submittal, please contact Paul Teichert (865-218-1028).

Sincerely,

AMEC Environment & Infrastructure, Inc.

Milly Vandegriff for

W. Paul Teichert
Senior Environmental Principal

Andrew M. Clark with permission
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Enclosure

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Acronym List

μg/L	micrograms per liter
μS/cm	microsiemens per centimeter
°C	degrees Celsius
AMEC	AMEC Environment & Infrastructure, Inc.
ASTM	American Society for Testing and Materials
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene and total xylenes
COC	contaminant of concern
CSM	conceptual site model
Declaration	Declaration of Covenants and Restrictions (2006)
DEM	digital elevation model
DNAPL	dense, non-aqueous phase liquid
DPT	direct push technology
DO	dissolved oxygen
Duke	Duke Energy
DRO	diesel range organics
EDTA	ethylenediaminetetraacetic acid
EPA	Environmental Protection Agency
FFS	Focused Feasibility Study
ft^2	square feet
g/L	grams per liter
GC/MS	gas chromatography and mass spectroscopy
gpm	gallons per minute
GRO	gasoline range organics
HSA	hollow-stem auger
ID	inside diameter
IR	PWR injection well
IS	shallow overburden injection well
ISCO	in-situ chemical oxidation
iSOC	in-situ oxygen curtain
ISOC	Pilot iSOC test well designation for well screened in the partially weathered rock
lbs	pounds
MCL	maximum contaminant level
MDL	method detection limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MGP	manufactured gas plant

MNA	monitored natural attenuation
msl	mean sea level
mV	millivolt
NAPL	non-aqueous phase liquid
NTU	nephelometric turbidity unit
OA2	total organic analysis
OD	outside diameter
OR	PWR observation well
ORP	oxidation reduction potential
OS	shallow observation well
PAH	polycyclic aromatic hydrocarbons
PID	photoionization detector
PNG	Piedmont Natural Gas Company
PVC	polyvinyl chloride
PWR	partially weathered rock
RBSL	Risk Based Screening Level
SCDHEC	South Carolina Department of Health and Environmental Control
Site	the former Spartanburg-Pine Street Manufactured Gas Plant
SOD	soil oxidant demand
SP	spontaneous potential
SU	standard unit
SVOC	semivolatile organic compound
TPAH	total polynuclear aromatic hydrocarbon
TPH	total petroleum hydrocarbon
UIC	Underground Injection Control
VOC	volatile organic compound
YSI	Yellow Springs Instruments

1.0 INTRODUCTION

The former Spartanburg-Pine Street Manufactured Gas Plant (Site) is located at 684 North Pine Street in Spartanburg, South Carolina. The Site encompasses a total area of approximately 7.4 acres (Figure 1). Manufactured Gas Plant (MGP) operations were conducted at the Site from the early 1900s to the mid-1950s. MGPs were industrial facilities that produced gas from coal, oil, or similar feedstocks. The primary wastes from the process were coal tar, emulsions of tar, oil and water, ash, and purifier wastes (lime and iron oxides). During historical operations, these materials were often released to the subsurface at various points of the process including the gas holders, tar separators, and tar wells.

Duke Energy (Duke) performed remedial investigation and remedial design of the Site in 2000 – 2003 and the selected remedial approach involved excavation of much of the overburden materials. Remedial action activities in 2003 and 2004 removed and properly disposed of approximately 67,596 tons of contaminated soil and debris.

Post excavation monitoring of on-site wells screened in the overburden and upper bedrock zone indicated hydrocarbons at concentrations above South Carolina Department of Health and Environmental Control's (SCDHEC) Risk Based Screening Levels (RBSLs). Based on these results, SCDHEC requested that Duke consider additional remedial alternatives relative to the shallow groundwater. Duke submitted a Focused Feasibility Study (FFS) for the Site to SCDHEC in 2008 (ENSR, 2008) that evaluated monitored natural attenuation (MNA), gas inFusion technology, in-situ chemical oxidation (ISCO), soil stabilization, and saturated zone excavation. Duke and SCDHEC agreed upon ISCO as the preferred alternative for shallow groundwater at the Site. Both parties agreed that pilot testing should be conducted prior to full-scale implementation.

A *Chemical Oxidation Pilot Test Work Plan* was prepared in May 2012 and approved by SCDHEC on June 26, 2012 (AMEC, 2012a). Underground injection well and monitoring well installation permit applications were subsequently prepared and submitted on July 26, 2012 (AMEC, 2012b & 2012c). The corresponding Underground Injection Control (UIC) permit applications were submitted on July 26, 2012 (AMEC, 2012b). These applications were approved for construction by SCDHEC on August 7 and August 14, 2012. Drilling work was conducted during September and October 2012. SCDHEC issued an UIC permit to operate on October 5, 2012. Data obtained during installation of the pilot wells was used to revise the initial loading estimates and a revised UIC permit application was submitted December 11, 2012 (AMEC, 2012d). Shallow zone pilot injections were initiated in December 2012 and completed in January 2013. Injections in the PWR were initiated in March 2013 but were terminated prior to completion based on certain unexpected geochemical measurements during the initial weeks. The UIC permit application was subsequently revised on July 26, 2013 (AMEC, 2013) and the revised injection conditions were approved on August 13, 2013. AMEC Environment & Infrastructure, Inc. (AMEC) has prepared this report summarizing the results of ISCO pilot test. Figure 1 depicts the pilot test area and layout of the pilot test injection and observation wells.

2.0 SITE BACKGROUND

2.1 Site Description

The location of the former Spartanburg-Pine Street Manufactured Gas Plant (Site) is 684 North Pine Street in Spartanburg, South Carolina. The Site encompasses a total area of approximately 7.4 acres (Figure 1). North Pine Street (US Highway 176) bounds the property to the west, and Norfolk Southern Railway mainline tracks form its northern boundary. The Site is bounded by other commercial/industrial property to its east and by Linder Street to the south. The property is located in a predominately commercial and industrial section of Spartanburg. Piedmont Natural Gas Company (PNG) presently owns the majority of the former MGP; the remainder of the Site is owned by Duke.

Chinquapin Creek flows through the approximate center of the Site, entering the Site from the northwest through a culvert beneath the Norfolk Southern Railway system railroad embankment. The creek flows southeasterly, then turns east and eventually flows beneath Fairview Avenue. A tributary of Chinquapin Creek enters the Site from the west through a culvert beneath North Pine Street and intersects with Chinquapin Creek. Chinquapin Creek eventually flows into Lawson Fork Creek approximately 3,600 feet from the Site.

2.2 Geological Setting

The Site is in the Piedmont physiographic province of South Carolina. This region extends from Alabama into Georgia, the Carolinas, Virginia, Maryland, Pennsylvania, and southeastern New Jersey. The rock formations of this region consist primarily of metamorphic rock formations, generally consisting of gneisses and schists of Precambrian age. Parallel banding, resulting from the segregation of minerals during metamorphism, characterize these crystalline rocks. The bands usually appear contorted or twisted, although they remain parallel and generally dip in a consistent direction. The metamorphic formations include various intrusive igneous rocks, such as granite and diabase. These igneous intrusions vary in size from large masses (hundreds of feet wide) to narrow bands (several inches wide). The igneous rocks are considerably younger than the metamorphic rocks, although the exact age is unknown (Sowers, 1954).

The Piedmont has experienced various episodes of heat, pressure, and structural deformation. Heat and pressure created varying degrees of metamorphism, while the structural deformations and folding produced joints and foliations. Joint set orientations are described as uniform in some areas and random in others.

Residual soils are products of physical and chemical weathering of the underlying bedrock. Depending on the degree of weathering, the soil can retain much of the fabric, or structural features, of the parent rock. Weathering generally decreases with depth. However, there is often no well-defined boundary between soil and rock.

The shallow geology within the Spartanburg area is generally comprised of igneous and metamorphic crystalline rocks that are generally foliated and fractured. The percolation of water downward through the fractures has resulted in the formation of a layer of residual weathered material (saprolite) and soil at the land surface. The saprolite unit retains the relict structure of the parent rock, although its strength resembles that of soil, it is considered a semi-permeable bed which may store and recharge water to the underlying bedrock aquifer.

Groundwater occurs within several zones beneath the Site: a shallow unconfined zone within the saprolite and a thin semi-confined zone within the partially weathered rock (PWR). Groundwater occurs within the saprolite and residuum between the clay, silt, and sand grains from approximately from 5.3 to 13 feet below ground surface (bgs). Groundwater elevations and direction of flow within the shallow aquifer from the most recent semi-annual sampling event are shown on Figure 2.

Partially weathered rock, with alternating seams of saprolite and weathered rock, occurs at depths of about 15 to 24 feet bgs. Groundwater flow also occurs within the PWR and underlying fractured bedrock along secondary features, joints, and planes of weakness. Figure 3 provides the groundwater elevations and flow direction in the fractured bedrock from the most recent semi-annual sampling event.

Vertical gradients are generally from the overlying overburden or saprolite to the bedrock. Some well pairs exhibit weak variations between vertical upward and downward gradients. However, vertical upward gradients are consistently exhibited at well pairs MW-14S/14D and MW-16S/16D.

2.3 Site Operational History

MGP operations were conducted at the Site from the early 1900s to the mid-1950s. MGPs were industrial facilities that produced gas from coal, oil, or similar feedstocks. The majority of the facilities produced gas from coal and the manufactured gas was used in the same manner as natural gas is used today. The coal gas manufacturing process generally consisted of the following steps:

- Coal was heated in retorts with little to no air;
- During heating, steam was injected which resulted in formation of water gas (a mixture of methane and carbon monoxide);

- Heating also volatilized light hydrocarbons which were subsequently condensed and either re-injected into the coal retort or collected for other uses; and

- A portion of the light hydrocarbons that were re-injected cracked to methane which increased the heating potential of the water gas.

The primary wastes from the process were coal tar, emulsions of tar, oil and water, ash, and purifier wastes (lime and iron oxides). The coal tars are highly viscous materials that have limited solubility and a density slightly greater than water. During operation of MGPs, these materials were often released to the subsurface at various points of the process including the gas holders, tar separators, and tar wells. Once released to the subsurface, these materials migrate vertically downward under the influence of gravity. Materials that have limited solubility and a density greater than water that migrate in the subsurface in a non-dissolved phase are referred to as dense non-aqueous phase liquids (DNAPL). The subsurface flow paths of these materials are generally not influenced by ambient hydraulic gradients, but are affected by interfacial tensions and the presence of subsurface low permeability layers. Groundwater flowing past DNAPL will result in dissolved phase plumes of contamination. Complete dissolution of DNAPL, as a result of natural groundwater flow, will require decades to hundreds of years.

The original plant had two gasholders and two tar wells. An additional gasholder and an aboveground tank were constructed on-site around 1950. By 1960, all three gasholders and the two tar wells were demolished. All equipment associated with the gas plant had been removed by 1964.

The Site is presently unoccupied and unused, but includes evidence of previous development. The most recent use of the Site was by PNG for natural gas supply and distribution. An existing Duke substation is situated just west of the PNG property boundary.

2.4 Summary of Previous Remedial Activities

Duke performed remedial investigation and remedial design of the Site in 2000 - 2003 and the selected remedial approach involved excavation of much of the overburden materials. Remedial excavation was performed in three phases from February 2003 to March 2004. Approximately 67,596 tons of contaminated soil and debris were removed from the Site and properly disposed. Although the excavation was extensive, all potentially impacted soils were not removed due to physical site constraints that included, but were not limited to, building foundations, property boundaries, railroad and utility right-of-way limits, and the presence of residuals below the water table.

A Trespasser Focused Risk Evaluation Report in 2004 determined that current site conditions do not pose unacceptable risks for industrial/commercial use scenarios. In 2006, a Declaration of Covenants and Restrictions (Declaration) was executed by PNG that restricted use of the property for residential, agricultural, recreational, child day care, schools, and elderly care facilities. Additionally, the institutional controls prohibit the use of groundwater for drinking or irrigation purposes without the approval of SCDHEC.

Post excavation monitoring of on-site wells screened in the overburden and upper bedrock zone indicated hydrocarbons at concentrations above SCDHEC's RBSLs. Groundwater monitoring results from the deeper bedrock well at the Site (MW-1DR), screened at approximately 40 feet below the top of bedrock, have not indicated any hydrocarbon contamination. Based on the post excavation monitoring results, SCDHEC requested that Duke consider additional remedial alternatives relative to the shallow groundwater.

Duke submitted a FFS for the Site to SCDHEC in 2008 (ENSR, 2008). The conceptual site model (CSM) presented in the FFS indicated that DNAPL and adsorbed hydrocarbons in the saturated zone soils and PWR were the primary sources of impacts to shallow overburden and bedrock groundwater. This CSM is intuitive considering the physical properties of the historically released material and the Site geology. Coal tar is slightly denser, but has a much greater viscosity than water. When it is released at or near surface, it migrates downward as a separate phase liquid under the influence of gravity. During downward migration, blobs, or ganglia, of the coal tar become entrapped in matrix pores. Geotechnical studies of the Piedmont indicate that the overburden soils are likely to have porosities on the order of 40% to 60%, and the PWR will exhibit porosities of 10% to 25%. These soil horizons have a much greater porosity than the underlying bedrock (<5%) and, therefore, will retain a much larger proportion of any DNAPL at the Site. Overburden soils and fine grained materials in voids in the PWR can also adsorb a far greater mass of hydrocarbons than can be adsorbed in partially filled fractures in the bedrock.

This CSM is also supported by certain trends in the monitoring data at the Site. Monitoring data from 2009-2011 indicate that concentrations of benzene, ethylbenzene, and trimethylbenzenes are generally greater in MW-13S than in MW-13D. Concentrations of these constituents in well MW-13 ISOC generally tend to be similar to those observed in MW-13S and greater than observed in MW-13D. Concentrations of polycyclic aromatic hydrocarbons (PAHs) are generally greater in wells MW-13S and MW-13 ISOC than in MW-13D. Concentrations of light aromatics and PAHs are greater in the shallow wells at locations MW-14S/14D and MW-18S/18D than in the deeper well. Conversely, at well pair MW-15S/15D concentrations of light aromatics are similar between the shallow and deeper well, but PAH concentrations tend to be greater in the deep well. The 2008 FFS evaluated MNA, gas inFusion technology, ISCO, soil stabilization, and saturated zone excavation. Gas inFusion technology, patented by inVentures, and commonly referred to as in-situ oxygen curtain (iSOC) was piloted in 2009 in the overburden, PWR, and deeper bedrock, but monitoring data demonstrated a very limited area of influence. SCDHEC provided comments to the FFS in a letter dated September 2, 2010 (Berresford to McGary). In May 2011, Duke and SCDHEC agreed upon ISCO as the preferred alternative for shallow groundwater at the Site. Both parties concurred that pilot testing of the approach should be conducted.

2.5 Contaminants of Concern

2.5.1 Contaminants of Concern in Soils

The Site was extensively characterized by grid sampling of soils that were analyzed using standard volatile organic compound (VOC) and semivolatile organic compound (SVOC) methods prior to excavation in 2003 and 2004. That characterization data was used to design remedial excavation which was implemented in three phases. Phase 1 excavation addressed the area of the former MGP operations north of Chinquapin Creek and was completed in July 2003. Phase 2 excavation addressed the areas west of Chinquapin Creek and was completed in October 2003. The third phase of excavation addressed the area south of the creek and was completed in early 2004. However, contamination in saturated soil remains.

Post excavation sampling results were summarized in *Soil Data Review Summary Duke Energy Pine Street MGP Site (*S&ME, 2011a*)*. Post excavation soils data in that report were presented as total polycyclic aromatic hydrocarbon (TPAH) concentrations rather than individual contaminants of concern (COC). Within the Phase 1 area there are TPAH concentrations as great as 43,075 milligrams per kilogram (mg/kg) remaining in unexcavated native soils at boring ARB-13. Very elevated TPAH concentrations also remain in unexcavated native soils at GP-33 (10,640 mg/kg), GP-30 (9,630 mg/kg), and ARB-43 (2,233 mg/kg). These soil samples were collected with the bottom of the sample interval at 11-12 feet bgs with the excavation terminating at 9-10 feet bgs. The water table in this area of the Site ranges from 4 to 6 feet bgs.

These data infer an area from slightly south of the gravel road extending approximately 90 feet to the north, and that is bounded west to east by borings TAS-002 and GP-30 (120 feet). Based on the data from the post-excavation borings, concentrations remaining in the unexcavated soil in this area may exceed 5,000 mg/kg (Figure 4).

As subsequently discussed in Section 4.0, the PAHs with the highest concentrations in this area are naphthalene, methyl naphthalenes, acenaphthene, anthracene, fluoranthene, chrysene, and phenanthrene. Naphthalenes, benzoanthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene are all at concentrations above SCDHEC RBSLs for protection of groundwater. VOCs that exceed the protection of groundwater RBSLs in the soils include benzene, toluene, ethylbenzene, and total xylenes (BTEX).

The Phase 2 area had one boring with a TPAH concentration greater than 20,000 mg/kg remaining (GP-78) and soils in the vicinity of two other borings with residual TPAH concentrations above 2,000 mg/kg may not have been completely excavated (Figure 4).

In the Phase 3 area across Chinquapin Creek, residual TPAH concentrations are lower than in the other two areas. The highest concentration of TPAH in a boring that may not have been completely excavated is 4,129 mg/kg at GP-73 and the average is 1,547 mg/kg in the other three borings with residual TPAH (Figure 4).

2.5.2 Contaminants of Concern in Groundwater

Benzene and naphthalene are the only contaminants with concentrations that exceed groundwater RBSLs. Groundwater flow north of Chinquapin Creek and in the Phase 2 area appears to be toward Chinquapin Creek.

Over the past five years, the wells with benzene and/or naphthalene concentrations above the groundwater RBSLs are MW-11D, MW-13S/13D, MW-13 ISOC, MW-14S/14D, MW-15S/15D, and MW-18S. Figures 5 and 6 present the historic groundwater monitoring results for shallow (overburden) wells in the Phase 1 area. Groundwater monitoring results for the past five years for shallow wells in the Phase 2 and 3 areas are presented in Figure 7. Historical groundwater monitoring results for 2009-2013 for the PWR and bedrock wells are presented in Figures 8 through 10.

Benzene concentrations in wells MW-14S and MW-15S appear to be relatively low and stable ranging from non-detect to 21.2 micrograms per liter (μg/L) between 2009 and 2013. During monitoring events in 2012 and 2013, benzene concentrations at MW-14S and MW-15S have dropped below the RBSL. Elevated and fluctuating benzene concentrations exist in saprolite (overburden) and PWR wells MW-13S and MW-13 ISOC with concentrations from 17.1 to 1240 μg/L from 2009 to 2012.

The only bedrock well with benzene above the RBSL has been MW-13D with concentrations ranging from 98-175 μg/L from 2009 to 2012. Benzene concentrations above the RBSL were not detected in the July/August, 2013 samples collected outside the pilot study area.

Over the past five years, naphthalene has exceeded the RBSL in shallow and PWR wells MW-13S, MW-13 ISOC, MW-14S, MW-15S, and MW-18S. Naphthalene concentrations are elevated and fluctuate significantly in the saprolite (overburden) wells north of Chinquapin Creek (MW-13S, MW-14S, MW-15S, and MW-18S). Concentrations of naphthalene have declined significantly in well MW-18S in 2012 and 2013 and were below the RBSL in 2013. Naphthalene is less prevalent in the saprolite wells south of Chinquapin Creek. Naphthalene concentrations in the bedrock wells north of Chinquapin Creek (MW-13D and MW-15D) fluctuate erratically, but over the past five years have exhibited a slightly increasing concentration trend. The concentrations of naphthalene in wells MW-13D and MW-15D in 2013 were significantly lower than observed in the preceding four years. Naphthalene concentrations in the bedrock well MW-11D south of Chinquapin Creek also fluctuate but exhibit a decreasing concentration trend over the same period of record monitoring.

Geologic and contaminant data indicate the majority of the contaminant mass is present in the saturated overburden soils and PWR as residual DNAPL and hydrocarbons adsorbed to soils. A significantly lesser mass of contaminants is likely present in the fractures of the upper bedrock zone.

3.0 PILOT TEST OBJECTIVES

3.1 Overall Remedial Objective

The CSM presented in the FFS indicated that DNAPL and adsorbed hydrocarbons in the saturated zone soils and PWR were the primary sources of impacts to shallow overburden and bedrock groundwater. This CSM is intuitive considering the physical properties of the historically released material and the Site geology. Coal tar is slightly denser, but has a much greater viscosity than water. When it is released at or near surface, it migrates downward as a separate phase liquid under the influence of gravity. During downward migration, blobs, or ganglia, of the coal tar become entrapped in matrix pores. Geotechnical studies of the Piedmont indicate that the overburden soils are likely to have porosities on the order of 40% to 60%, and the PWR will exhibit porosities of 10% to 25%. These soil horizons have a much greater porosity than the underlying bedrock (<5%) and, therefore, will retain a much larger proportion of any residual DNAPL at the Site. Overburden soils and fine grained materials in voids in the PWR can also adsorb a far greater mass of hydrocarbons than can be adsorbed in partially filled fractures in the bedrock.

This CSM is also supported by certain trends in the monitoring data at the Site. Monitoring data from 2009-2011 indicate that concentrations of benzene, ethylbenzene, and trimethylbenzenes are generally greater in MW-13S than in MW-13D. Concentrations of these constituents in well MW-13 ISOC generally tend to be similar to those observed in MW-13S and greater than observed in MW-13D. Concentrations of PAHs are generally greater in wells MW-13S and MW-13 ISOC than in MW-13D. Concentrations of light aromatics and PAHs are greater in the shallow wells at locations MW-14S/14D and MW-18S/18D than in the deeper well. Conversely, at well pair MW-15S/15D concentrations of light aromatics are similar between the shallow and deeper well but PAH concentrations tend to be greater in the deep well.

Post excavation TPAH sampling results summarized in *Soil Data Review Summary Duke Energy Pine Street MGP Site (*S&ME, 2011a*)* indicated soils in some locations with concentrations greater 2,000 mg/kg. In a few locations, soils with TPAH concentrations of greater than 10,000 mg/kg remain in place. TPAH concentrations at and above 10,000 mg/kg approach or may exceed residual saturation. Concentrations of TPAHs in the unexcavated soils of 1000-2000 mg/kg or above are indicative of residual DNAPL in the overburden and PWR.

Sites with residual DNAPL present challenges to remediation. Residual non-aqueous phase liquid (NAPL) may be displaced from the release point to locations that are difficult to access. Since residual DNAPL is not mobilized by advective flow, certain removal techniques are largely ineffective. Additionally, most in-situ chemical approaches are aqueous phase reactions that require dissolution from the NAPL mass for destruction to occur. Where residual DNAPL is present at a site, achievement of maximum contaminant levels (MCLs) or RBSLs in groundwater may be technically impracticable.

Remediation of impacted groundwater requires either physical removal techniques or delivery of chemical reactants to the affected zones. Alluvial soils and saprolite in the overburden are at shallow depths and are relatively permeable which provides a greater probability of remedial success. Physical or chemical remediation of the PWR is more difficult than the overburden, but may be achievable to some extent because this zone exhibits a reasonable degree of porosity. Contamination present in the fractures of the upper bedrock will be the most difficult to remediate because the limited porosity of this zone significantly impedes contact between contaminants and reagents.

Accordingly, the overall remedial objective for the Site is to reduce contaminant mass to the extent practicable. Significant reduction in contaminant mass in the upper soil horizons will reduce the concentrations of the COCs in shallow groundwater in a relatively limited period of time. Reduction in contaminant mass in these zones will also reduce the concentrations of the COCs in the shallow bedrock groundwater over time since the source has been reduced.

3.2 Pilot Study Objectives

The revised FFS proposed ISCO as the preferred alternative. The oxidant system selected for this Site was activated persulfate. The effectiveness of activated persulfate for remediation of hydrocarbons in groundwater has been demonstrated at numerous sites exhibiting differing soil characteristics and a wide range of contaminant concentrations.

Application of activated persulfate requires determination of the concentrations of the COCs in soil and groundwater in the target area. Reduced minerals and organic matter in the native soils also exert a demand on the oxidant (referred to as Soil Oxidant Demand) which must be determined by bench testing using Site soils to properly dose the target interval. The ratio of the activator to oxidant mass is a function of the specific chemistry, but it can also be influenced by naturally occurring and anthropogenic species in the soils. Accordingly, activator demand must also be determined in bench tests using Site soil.

Injection of the reagents at rates or pressures that exceed the limits of the aquifer matrix will result in daylighting or surfacing of reagent and flows along preferential pathways that may not provide contact with the contaminants. Although injection patterns are generally elliptical, they may be displaced from normal axes by subsurface conditions and the aspect ratio of the axes and area of influence must be verified by field testing. Therefore, pilot testing is generally conducted to determine proper injection conditions, injectate distribution patterns, and the area of influence from the injection point.

In the PWR, injectate flow will be limited to some degree by fracture patterns and weathering related channels. To develop the Work Plan, a first order fracture trace analysis was completed based on the topographic contour map of the Spartanburg area. Using lineament analyses and geophysical surveys, subsurface bedrock fracture zones, and potential zones of higher groundwater flow rates were identified. Flow patterns in the PWR will also be dependent on the extent of weathering and may deviate from the regional fracture orientation. Therefore, it will be necessary to verify that observation wells are likely screened into fractures interconnected with the injection well. Additionally, piloting is needed to determine if an appreciable volume of oxidant solution can be injected into the PWR at reasonable pressures and flow rates.

Accordingly, the objectives of this Pilot Study were:

1. Determination of contaminant mass in the soil and groundwater in the target area,
2. Determination of soil oxidant demand (SOD) and activator demand to determine oxidant and activator dosing,
3. Evaluation of injection distribution patterns,
4. Evaluation of the injection area of influence,
5. Evaluation of injection parameters (pressures and flow rates) that are within the formation limits,
6. Evaluation of fracture patterns in the bedrock to assist in evaluating likely flow patterns in the PWR, and
7. Evaluation of the practicality of injection into the PWR.

A *Chemical Oxidation Pilot Test Work Plan* was prepared in May 2012 and approved by SCDHEC on June 26, 2012. Beginning in September 2012, AMEC implemented a pilot test to investigate the effectiveness of base-activated sodium persulfate as a chemical oxidant for the remediation of MGP contaminants in the shallow (overburden) aquifer and into the fractured PWR. The Pilot Study was intended to obtain data in support of full scale remediation. The vicinity of wells MW-13S, MW-13 ISOC, and MW-13D was selected for conducting the Pilot Study.

4.0 SUMMARY RESULTS OF SOIL AND GROUNDWATER TESTING TO SUPPORT PILOT TESTING

4.1 Determination of Contaminant Mass

4.1.1 Soil

ISCO requires determination of the concentrations of the COCs in soil in the target area in order to determine the oxidant loading. As previously noted, Site soils were characterized by Environmental Protection Agency (EPA) Method 8260 (VOCs) and Method 8270 (SVOCs) to support remedial design in 2003 and 2004. MGP residuals contain short chain and long chain aliphatic hydrocarbons that are not quantified by these methods. Hydrocarbons species not quantified by these methods may be equal to 30% to 50% of the mass of the aromatic hydrocarbons and will exert demand for any injected oxidant.

Soil concentrations of VOCs and SVOCs in the pilot area were not available at the beginning of the study. Soil sample GP-24 was obtained in closest proximity to the pilot test area but was approximately 30 feet to the west of the pilot study area. That sample exhibited a post-excavation TPAH concentration of 282 mg/kg. The *Chemical Oxidation Pilot Test Work Plan* acknowledged the absence of soils data in the immediate area and indicated that adequate characterization of both VOCs and PAHs in the pilot study area was a primary study objective.

Initial estimates of soil concentrations for BTEX and PAHs, were calculated for the Work Plan using equilibrium partitioning calculations. For the initial loading estimates, the mass of light and heavy aliphatics was assumed to be 40% of the aromatics estimated to be present in soil from the partitioning calculations. This approach was combined with an estimated area of influence of approximately 850 square feet (ft^2) and a saturated thickness of approximately 7 feet. The total mass of the various hydrocarbon fractions in the pilot area was estimated to be approximately 156 pounds (lbs).

During installation of the observation wells in late September 2012, soil samples were collected from soil boring location SOD-4 (Figure 11) and the borings for wells OS 5S, OS 10S, and OS 20S (Figure 1). These soil samples were analyzed for VOCs and SVOCs by Methods 8260 and 8270, respectively, and total petroleum hydrocarbon (TPH). TPH, or total organic analyses (OA2), differs from VOC and SVOC analyses because it provides a gross determination of all hydrocarbons within a given carbon range rather than quantification of only the individual analytes within the gas chromatography and mass spectroscopy (GC/MS) libraries of Methods 8260 and 8270. TPH analysis of the soil samples included TPH-Gasoline Range Organics (TPH-GRO) and TPH-Diesel Range Organics (TPH-DRO). TPH-GRO quantifies both aliphatic and aromatic hydrocarbons in the C6-C10 range and TPH-DRO quantifies organics in the C10-C28 range.

Results for detected VOCs and TPH-GRO for pilot area soils are provided in Table 1. Table 2 summarizes detected SVOCs and TPH-DRO results for the soils in the pilot study area. Laboratory analytical reports are provided in Appendix A. Soil concentrations of ethylbenzene, xylene, alkyl benzenes, and TPH-GRO were 5 to 10 times greater than in the initial estimates based on equilibrium partitioning calculations. Concentrations of naphthalene, several other PAHs, and TPH-DRO were also several times greater than the initial estimates. Additionally, the soil concentrations of BTEX, alkyl benzenes, naphthalene, and TPH were elevated at boring OS 5S relative to other borings in the study area. For example, BTEX and alkyl benzenes at boring OS 5S totaled 299 mg/kg versus a mean of 44 mg/kg in the other borings. Naphthalene was also elevated at OS 5S (1,460 mg/kg) versus a mean at the other borings of 214 mg/kg. Such disparities are not uncommon in soil results due to heterogeneities in the soil matrix and contaminant distribution in soil pores.

Table 1. Detected VOCs and TPH-GRO for Pilot Area Soils

	RBSLs*	OS 10S	OS 20S	OS 5S	SOD-4
VOCs					
1,2,4-Trimethylbenzene	NA	23.4	17.1	123	20.8
1,3,5-Trimethylbenzene	NA	11.5	8.18	38.5	8.26
Acetone	NA	<0.0583	<0.0523	0.11	0.0479
Benzene	0.007	0.00704	0.00278	0.0314	0.105
Carbon disulfide	NA	<0.0583	<0.00523	0.00788	0.00896
Chloroform	NA	<0.00233	<0.00209	0.0136	<0.00191
Ethylbenzene	1.150	8.16	4.09	63.4	7.17
Isopropylbenzene	NA	3.27	1.37	16.1	2.71
Naphthalene	0.036	331	135	1,460	178
n-Butylbenzene	NA	0.132	2.53	12.4	<0.119
N-Propylbenzene	NA	0.123	1.29	8.11	1.70
p-Isopropyltoluene	NA	0.12	1	8.57	1.90
sec-Butylbenzene	NA	0.00932	<0.296	<0.287	<0.119
Toluene	1.450	0.0549	0.0416	0.565	0.0330
Xylenes, Total	14.500	5.76	4.05	40.6	4.80
TPH-GRO					
C6-C10	NA	91.5	24.2	563	30.9

* RBSLs for sandy soils rather than clay soils were used for comparison.

Notes: Soil samples collected September 7 and September 26, 2012
Units are in milligrams per kilogram (mg/kg)
Values shaded in grey exceed the soil RBSL

< = not detected at reporting limit
NA = none available
RBSL = Risk Based Screening Level
TPH-GRO = total petroleum hydrocarbon-gasoline range organics
VOC = volatile organic compound

Table 2. Detected SVOCs and TPH-DRO for Pilot Area Soils

	RBSLs*	OS 5S	OS 10S	OS 20S	SOD-4
SVOCs					
1-Methyl naphthalene	0.036	28	4.54	20.7	37.2
2-Methyl naphthalene	0.036	42.3	5.24	37.6	3.53
Acenaphthene	NA	12.3	2.58	1.27	18.9
Acenaphthylene	NA	1.33	0.266	8.06	1.69
Anthracene	NA	4.94	0.919	4.1	8.38
Benzo[a]anthracene	0.066	2.47	0.371	2	2.89
Benzo[a]pyrene	NA	2.22	0.335	1.88	2.46
Benzo[b]fluoranthene	0.066	1.41	0.173	1.03	1.28
Benzo[g,h,i]perylene	NA	0.764	0.116	0.712	0.819
Benzo[k]fluoranthene	0.066	1.11	0.22	0.996	1.45
Carbazole	NA	<0.405	<0.396	<0.423	0.454
Chrysene	0.066	1.94	0.287	1.55	2.20
Dibenz(a,h)anthracene	0.066	0.246	<0.0797	0.209	0.256
Dibenzofuran	NA	1.95	0.407	1.59	2.91
Fluoranthene	NA	5	0.902	4.57	8.58
Fluorene	NA	6.03	1.29	3.55	10.7
Indeno[1,2,3-cd]pyrene	NA	0.628	0.0929	0.581	0.689
Naphthalene	0.036	64.6	11.6	38.9	28.7
Phenanthrene	NA	17.2	3.44	14.9	31.7
Pyrene	NA	7.98	1.44	6.86	11.5
TPH-DRO					
C10-C28	NA	642	262	227	1,760
C24-C40	NA	88	49.3	32.5	352

* RBSLs for sandy soil rather than clay soils were used for comparison.

Notes: Values shaded in grey exceed the soil RBSL. RBSL for methyl naphthalenes is 0.036 mg/kg for combined isomers
Soil samples collected September 7 and September 26, 2012
Units are in milligrams per kilogram (mg/kg)

< = not detected at reporting limit
NA = none available
RBSL = Risk Based Screening Level
SVOC = semivolatile organic compound
TPH-DRO = total petroleum hydrocarbon-diesel range organics

In order to account for the elevated concentrations at OS 5S, the masses of the various hydrocarbon fractions were estimated by assuming that the data from OS 5S applied only to a limited area in its immediate vicinity and that mean soil concentrations based on the other soil samples applied to the remaining area of influence. Based on this approach, the total mass of hydrocarbons in the pilot area was estimated at approximately 350 lbs.

Additional soil samples for VOCs, SVOCs, and TPH were collected during this part of the Pilot Study to preliminary design. These samples were collected at locations SOD-5 and SOD-6 (Figure 11). Results for detected VOCs and TPH-GRO for these sample locations are provided in Table 3. Results for detected SVOCs and TPH-DRO for these sample locations are provided in Table 4.

Table 3. Detected VOCs and TPH-GRO in Soil for SOD-5 and SOD-6

	RBSLs*	SOD-5	SOD-6
VOCs			
1,2,4-Trimethylbenzene	NA	4.57	118
1,3,5-Trimethylbenzene	NA	1.49	41.9
Benzene	0.007	0.150	<1.93
Ethylbenzene	1.150	1.64	69.6
Isopropylbenzene	NA	0.468	14.2
Naphthalene	0.036	45.6	2,050
n-Butylbenzene	NA	<0.144	9.25
N-Propylbenzene	NA	0.335	5.85
p-Isopropyltoluene	NA	0.413	7.66
Toluene	1.450	0.011	22.1
Xylenes, Total	14.500	1.69	122
TPH-GRO			
C6-C10	NA	33.2	137

* RBSLs for sandy soil rather than clay soils used for comparison.

Notes: Units are in milligrams per kilogram (mg/kg)
Values shaded in grey exceed the soil RBSL
Soil samples collected September 26, 2012

< = not detected at reporting limit
NA = none available
RBSL = Risk Based Screening Level
TPH-GRO = total petroleum hydrocarbon-gasoline range organics
VOC = volatile organic compound

Table 4. Detected SVOCs and TPH-DRO in Soil for SOD-5 and SOD-6

	RBSLs*	SOD-5	SOD-6
SVOCs			
1-Methyl naphthalene	0.036	130	28.6
2-Methyl naphthalene	0.036	114	18.8
Acenaphthene	NA	54.5	46.3
Acenaphthylene	NA	3.92	30.1
Anthracene	NA	23.8	102
Benzo[a]anthracene	0.066	9.15	90.1
Benzo[a]pyrene	NA	7.39	87.2
Benzo[b]fluoranthene	0.066	3.18	73.7
Benzo[g,h,i]perylene	NA	1.64	39.8
Benzo[k]fluoranthene	0.066	3.07	54.3
Carbazole	NA	2.01	3.22
Chrysene	0.066	6.74	71.8
Dibenz(a,h)anthracene	0.066	0.552	13.4
Dibenzofuran	NA	11.6	57.9
Fluoranthene	NA	23.0	275
Fluorene	NA	25.8	94.0
Indeno[1,2,3-cd]pyrene	NA	1.61	36.5
Naphthalene	0.036	126	30.7
Phenanthrene	NA	90.9	284
Pyrene	NA	29.2	189
TPH-DROs			
C10-C28	NA	2,650	41,500
C24-C40	NA	465	13,800

* RBSLs for sandy soil rather than clay soils used for comparison.

Notes: Units are in milligrams per kilogram (mg/kg)
Values shaded in grey exceed the soil RBSL. RBSL for methyl naphthalenes is 0.036 mg/kg for combined isomers
Soil samples collected September 26, 2012

--- = no data
< = detection below reporting limit
NA = none available
RBSL = Risk Based Screening Levels
SVOC = semivolatile organic compound
TPH-DRO = total petroleum hydrocarbon-diesel range organics

4.1.2 Groundwater

Proper oxidant loading requires the determination of the concentrations of the COCs in groundwater in the target area. Groundwater data for VOCs and PAHs were available from wells MW-13S and MW-13 ISOC in the pilot study area. In order to estimate oxidant loading for the pilot test, maximum groundwater concentrations of BTEX, alkyl benzenes, and PAHs from wells MW-13S and MW-13 ISOC from 2009-2011 were used. A total BTEX and alkyl benzene concentration of approximately 2.8 milligrams per liter (mg/L) was estimated from this data. A total PAH concentration of 4.9 mg/L was similarly estimated. Total aliphatic hydrocarbon concentrations in the groundwater were estimated at approximately 45% of the aromatic concentrations.

Groundwater samples were collected from the shallow observation wells in the pilot study area during the first week of October 2012. Results for detected VOCs, SVOCs, TPH-GRO, and TPH-DRO are presented in Section 7 as baseline conditions. The results of the sampling indicated BTEX and light hydrocarbon concentrations similar to historic results at MW-13S. However, PAH and TPH-DRO concentrations in groundwater from these wells were several times greater than previously estimated from historic data. These data were also used to adjust oxidant loading for pilot injections in the overburden.

Data from the October 2012 sampling of well MW-13 ISOC was used to revise the estimate of the BTEX, PAH, and TPH-DRO mass in groundwater in the PWR area of influence. Mean soil concentrations from the study area were used to revise the estimated mass of the various hydrocarbon fractions in the soils within fractures. These data were subsequently used to adjust oxidant loading for pilot injections in the PWR.

4.2 Determination of Soil Oxidant and Activator Demand

SOD is a function of the reduced minerals and organic species in native soils. To properly determine SOD, the soil samples must be free of contamination and representative of the treatment zone. If contamination is present in the samples, oxidant demand is increased, and a true background SOD cannot be determined. SOD can vary by as much as an order of magnitude depending on the oxidant, soil types, and mineralogy.

Sodium persulfate oxidation chemistry generally relies on the generation of sulfate free radicals through a process referred to as activation. Activation is achieved by addition of heat or through the use of chemical activators. Activator demand is a function of the mols of activator required by the oxidant for proper free radical propagation. It is also influenced by the soil chemistry in the target intervals. For base and peroxide activated persulfate, the activator demand is also influenced by side reactions with hydrocarbons, such as saponification or incomplete oxidation reactions.

Sodium hydroxide activated persulfate is more commonly employed than the other chemically activated persulfate systems due to the simplicity of its activation system. Hydroxide activated persulfate offers additional advantages because it is one of the more aggressive persulfate oxidation systems addressing a wider range of contaminants than iron ethylenediaminetetraacetic acid (EDTA) activated persulfate, and it is relatively persistent in the subsurface. Sodium hydroxide activated persulfate also enhances desorption of petroleum hydrocarbons from the soil matrix. Sodium hydroxide activated persulfate was selected as the initially preferred oxidation chemistry.

A second oxidant activation system was selected to evaluate activator impact on full scale remediation economics. Hydrogen peroxide activation is generally considered the most aggressive chemically activated persulfate oxidation system. Superoxide radicals that are generated from the process are believed to enhance hydrocarbon desorption from soils and residual DNAPL thereby enhancing contaminant destruction rates. Both of these characteristics are desirable for oxidation of MGP related contaminants. The primary disadvantages of peroxide activated persulfate are some heat and gas generation and less persistence in the subsurface than other systems. Hydrogen peroxide activation was selected as the second persulfate chemistry for the initial bench tests due to its favorable oxidative power and ability to enhance contaminant mobility to the aqueous phase.

Activator demand is routinely determined in conjunction with SOD because SOD and activator demand are interdependent for a given oxidant system. Activator demand in relatively clean soil samples for SOD will be lower than needed in the contaminated areas where piloting and full scale ISCO would be implemented. Therefore, samples for SOD/activator demand were collected from both relatively clean soils and from areas of known contamination.

Much of the Site was excavated in 2003-2004, and native soils were replaced with fill and thermally treated soil. The pilot study area is located in the prior Phase 1 excavation area, northeast of Chinquapin Creek. Cross sections from the vicinity of MW-13S and much of the area north of the access road that would be targeted for remediation by ISCO show both fill and native alluvium in the saturated zone. A layer of saprolytic soil is also present in the saturated interval in the northeast portion of the Phase 1 excavation area (S&ME, 2011b). In order to determine the appropriate quantity of persulfate required, soil samples were collected and sent to FMC Environmental Solutions in Tonawanda, New York, for SOD and activator demand analysis. This analysis is designed to allow for proper oxidant loading calculations by accounting for all the oxidant sinks that are present in site-specific soils and groundwater, in addition to the target contaminants. Samples of all three types of soil are needed to obtain SOD data for the target interval for both the pilot area and broader application of ISCO across the Site.

Soil samples for SOD and activator demand were collected at the locations shown in Figure 11.

- SOD sample 1 (SOD-1/AVTR-1) was collected in the vicinity of historical soil sample GP-50. This area is northwest of the bridge over Chinquapin Creek. Historical data indicated little or no contamination in this area and that it was not excavated. Soil sample SOD-1 represents clean, undisturbed alluvium.

- The second set of samples for SOD was taken in the vicinity of historical soil sample ARB-161, located in the southeast portion of the Site. The area around historical soil sample location ARB-161 was not contaminated, but excavation did occur in this area. Soil sample SOD-2/AVTR-2 represents uncontaminated fill and alluvium.

- The third set of set of samples for SOD (SOD-3/AVTR-3) was taken in the vicinity of historical boring B-3, located in the northeast portion of the Site. The area around historical boring location B-3 was not contaminated and was outside the limits of excavation of the Phase 1 removal. Sample SOD-3 represents uncontaminated saprolyte soil. These soils are expected to be geochemically very similar to the PWR and therefore data obtained from this sample will be useful for designing oxidant loading for the overburden in portions of the Site with a significant layer of saprolite and the PWR.

- One sample for SOD was collected from soils with residual contamination from the pilot study area (SOD4/AVTR4). Material for this sample was collected from the saturated alluvium at approximately 677 to 682 feet mean sea level (msl). A sample for testing of SOD and activator demand using hydrogen peroxide was not collected at this location.

- Based on data from Phase 1 Assessment (Duke, 2002) and Final Soil Excavation Summary Report (Duke, 2006), SOD-5/AVTR-5 was collected from an area of residual contamination in the vicinity of historical soil sample TAS-002 (Figure 11). Sample material at this location was collected at the saturated fill/saprolite interface at approximately 680 to 682 feet msl. This historical sample location in the Phase 1 excavated area had a TPAH concentration of 740 mg/kg, which is similar to the mean residual TPAH concentration at the Site excluding sample locations greater than 3,000 mg/kg. Sample material from this location was submitted for SOD and activator demand testing using both hydroxide and hydrogen peroxide based activation.

- The final SOD sample (SOD-6AVTR-6) was collected from an area of residual contamination near historical soil sample ARB-43 (Figure 11). Sample material at this location was collected at the saturated fill/saprolite interface at approximately 680 to 682 feet msl. This historical sample location in the Phase 1 excavated area had a TPAH concentration of 2,233 mg/kg, which provides a range of conditions from which contaminant related effects can be determined.

Laboratory analytical reports are provided in Appendix A. The results from the "clean" soils had reported SOD values ranging from 0.37 to 1.45 grams of persulfate per kilogram of saturated aquifer material. The results from soils with residual contamination had reported SOD values ranging from 1.59 to 6.16 grams of persulfate per kilogram of saturated aquifer material. Samples containing MGP contaminants were expected to have a higher SOD than uncontaminated soil samples.

Activator demand for sodium hydroxide ranged from 0.47-0.75 gallons of solution per ton of soil. In the hydrogen peroxide activated system, 95% of the sodium persulfate and hydrogen peroxide were consumed within 96 hours of dosing the soil samples.

5.0 EVALUATION OF SHALLOW ZONE INJECTION PARAMETERS

5.1 Shallow Injection and Observation Well Installation

One Class VA-I injection well and eight observation wells were drilled, installed, and developed by a South Carolina certified well driller following all applicable requirements of the South Carolina Well Standards R.61-71 under monitoring well approval SF-12-15 and UIC Permit to Construct SCHE03020183M between September 25 and September 27, 2012. The locations of the shallow injection and observation wells are shown on Figure 12. The water well record forms were provided in a letter dated November 12, 2012 from AMEC to SCDHEC (AMEC, 2012e).

Borings were advanced from the ground surface using hollow-stem auger (HSA) drilling methods. A nominal 8-inch outside diameter (OD) X 4.25-inch inside diameter (ID) borehole was advanced to the top of the PWR.

The shallow overburden injection well (IS) is screened from approximately 8 to 13 feet bgs. The shallow observation wells (OS) are also screened between 8 to 13 feet bgs. Well identification numbers for the shallow observation wells are: OS 5E, OS 10E, OS 5N, OS 5S, OS 10S, OS 15S, OS 20S, and OS 25S. Well identification numbers indicate the direction and approximate distance from the injection well (i.e., OS 15S is 15 feet south of the injection well). Observation well OS 25S was installed since the shallow pilot injection area was moved to the east from its original planned location due to shallow refusal that did not allow for MW-13S to be used as a monitoring point. Figure 13 provides a cross section for the shallow injection and observation points.

A Type II, Schedule 40 polyvinyl chloride (PVC), 2-inch-diameter well constructed from threaded and gasketed riser pipe, with a 5-foot factory slotted (0.010-inch) well screen and threaded end cap was set through the augers. Drilling and well completion activities were guided by South Carolina Well Standards R.61-71 and American Society for Testing and Materials (ASTM) D 5092. The filter pack material consisted of a clean, rounded to well-rounded, quartz silica sand of 10/30 sieve size, also referred to as GP#2. A minimum of 6 inches of filter pack was placed below the bottom of the well screen. The augers were slowly extracted as the filter pack was tremied into place using a 1-inch PVC tremie pipe lowered between the screen/casing and the augers. The filter pack was extended a minimum of 2 feet above the top of the well screen. A bentonite seal of a minimum 2-foot vertical thickness, consisting of 3/8-inch bentonite chips, was placed above the sand pack and hydrated with potable water. Following seal hydration, the remaining annulus was filled with neat cement grout. The monitoring wells were completed at the surface with a locking expansion cap set into the top of the 2-inch PVC casing; a 2-foot square, 4-inch thick concrete pad; and a 4-inch square steel well protector (stick-up). After the grout set, the wells were developed using a peristaltic pump such that clear, sediment free water was produced. Drilling wastes (cuttings and development water) were collected and placed in drums for off-site disposal.

5.2 Step Injection Test

5.2.1 Step Test Procedure

The delivery rates for remedial reagents are always site-specific. A step injection test was conducted in order to determine sustainable aquifer injection rates and pressures for remedial injection design at this Site. The injection step test stimulated the aquifer through constant injection at a preset rate and pressure.

During the step injection test, potable water was introduced into the subsurface via a 1-inch injection well at a given pressure and flow rate. The injectate volume for each step was initially set at 1,000 gallons to simulate the volume of injectate anticipated during a subsequent injection of oxidant in the test area. At each set pressure and flow condition or “step” injection was completed until the set injection volume was reached, excessive mounding occurred (more than 3 to 4 feet at the observation wells closest to the injection well), or sufficient time passed without any significant change in mounding. Groundwater mounding occurs in response to the fluid injection as pressure in the formation rises.

Pre-injection monitoring consisted of measurement of the water levels in the observation wells and at a few background wells. This data was used to validate the water table elevation just prior to injection and established a baseline to evaluate mounding in the aquifer from the subsequent injection events. During injection, water-level measurements were collected at the side and downgradient observation wells. Pressure transducers were deployed within observation wells surrounding the injection well to monitor the response within the aquifer to the injection.

In order to prevent surfacing, development of preferential pathways, or fracturing of soils, injection pressures and flow rates need to be kept at moderate levels. Moderate injection conditions that do not significantly stress the formation also ensure good distribution. Flow rates for piloting were kept below an estimated maximum sustainable formation “take” rate of 5 gallons per minute (gpm) to reduce the possibility of excessive mounding. Pilot injection pressures were selected to provide adequate head at the injection point without fracturing soils or development of preferential pathways.

The injection step test used four different injection rates and two injection pressures as shown in Table 5.

Table 5. Overburden Injection Step Test Parameters

Test Number	Flow Rate (gpm)	Pressure (psi)	Injection Volume (gallons)
1	5	10	150
2	1	5	600
3	1	10	500
4	2.5	5	1,000
5	3.0	5	1,100

gpm = gallons per minute
psi = pounds per square inch

After completion of each injection rate test, a sufficient time for relaxation of the mounding to within 10% to 20% of baseline was allowed before beginning the next step of the test. Water elevation data from each transducer was plotted versus time and segregated by step test as shown in Appendix B.

5.2.2 Step Test Results

The initial step test for the overburden was proposed in the Work Plan as 5 gpm at a pressure of 10 pounds per square inch (psi). This test was performed as planned, but was terminated after thirty minutes due to mounding of greater than 4 feet in the observation wells. Due to its short nature, this test was disregarded for analysis of the transducer data and subsequent tests were performed at a lower flow rate. This test established that the upper bound for the injection flow-rate was less than 5 gpm.

In step tests 2 and 3, it was decided to inject at the lower bound rate of approximately 1 gpm. The water elevation in the overburden wells rapidly rose upon initiating the injection and subsequently rose at a slower steady rate as the injection progressed. Mounding that occurred was a short lived phenomenon as the aquifers recovered within minutes to hours. Upon termination of each step test, groundwater elevations rapidly recovered to baseline levels following a logarithmic curve. During the overburden step tests, water elevations in the PWR generally rose incrementally with time. Once the step test was complete, mounding in the PWR wells recovered to baseline conditions in a logarithmic fashion similar to the overburden wells. These general trends indicated that the PWR is hydraulically connected with the overburden.

Step test 2 had a flow rate of 1 gpm, pressure of 5 psi, and used a total volume of 600 gallons. Mounding within the overburden in the downgradient direction varied from a high of 2.05 feet at OS 5S to a low of 1.36 feet at OS 15S. Typically, mounding decreases with distance from the injection well; however, OS 15S had less mounding (1.36 feet) than OS 25S (1.87 feet) even though it is closer to the injection well. The reduced mounding at OS 15S indicates that the well is impacted by a local inhomogeneity (e.g., soil particle size, micro-fracture) within the overburden that alters the response to the injection as compared to the other observation wells. In the cross-gradient direction, data from the pressure transducer in OS 5E was corrupted. Observation well OS 10E mounded 1.07 feet and well OS 5N in the upgradient direction mounded 1.93 feet. Mounding in the upgradient direction was slightly less than the 2.05 feet of elevation change at the equidistant downgradient well OS 5S. Step test 2 indicated that short-circuiting did not occur at 1 gpm and proper injectate distribution was achieved. Mounding in the PWR observation wells varied from 0.88 to 1.15 feet, indicating that they were influenced by the injection in the overburden and are hydraulically connected.

Step test 3 was conducted a day after step test 2, after aquifer recovery was confirmed by gauging select observation wells. Step test 3 was performed at 1 gpm and 10 psi, with a total volume of 500 gallons. Mounding within the overburden in the downgradient direction decreased with distance from the injection well from observation well OS 5S (1.72 feet) to OS 25S (1.25 feet). Greater mounding occurred in the downgradient wells than the wells equidistant in the cross-gradient direction. Observation well OS 10S displayed a water elevation change of 1.40 feet while OS 10E mounded 0.98 feet. Upgradient observation well OS 5N (1.76 feet) exhibited similar mounding to the equidistant downgradient well, OS 5S (1.72 feet). The increased delivery pressure caused the injection pattern to become more elliptical in nature with a preference toward the downgradient direction. Mounding in the PWR observation wells increased slightly from the levels observed in step test 2 due to the increased delivery pressure, and varied from 0.82 to 1.61 feet.

Step test 4 involved injection of a total volume of 1,000 gallons at a flow rate of 2.5 gpm and pressure of 5 psi. The flow rate was increased to 2.5 gpm for this test in an attempt to define an acceptable injection rate and consequently increase or decrease the injection rate for subsequent tests. Mounding significantly increased from prior step tests in all observation wells, exceeding or coming close the predetermined threshold of 4.0 feet at observation wells nearest the injection well. In the downgradient direction, mounding decreased with distance from the injection well from observation point OS 5S (4.03 feet) to well OS 25S (2.94 feet). Observation wells located 5 feet from the injection well in the up and downgradient direction exhibited comparable mounding to the closest observation well in the downgradient direction, with mounding at well OS 5S of 4.03 feet and mounding at well OS 5N of 3.89 feet. The cross-gradient direction displayed less mounding than the downgradient well equidistant from the injection well, with an elevation change at well OS 5E of 3.57 feet compared to OS 5S (4.03 feet). Increased mounding in the downgradient direction versus the cross-gradient direction was more pronounced at greater distance from the injection well as indicated by comparing the change at well OS 10E (2.17 feet) to OS 10S (3.32 feet). This indicates that at a flow rate of 2.5 gpm, the injectate is being properly distributed in an elliptical pattern in the downgradient direction and is not short-circuiting. Mounding in the PWR observation wells was consistent with prior step tests, increasing as the delivery flow rate increased, and ranged from 1.67 to 2.36 feet.

Step test 5 was conducted at a delivery pressure of 5 psi with a total volume of 1,100 gallons. The flow rate for step test 5 was increased to 3.0 gpm to establish the upper bound of acceptable injection flow rates for the overburden. Mounding in OS 5S, OS 10S, and OS 5E was greater than the accepted limit of 4.0 feet, indicative that the maximum injection rate for the overburden had been exceeded. Consistent with previous step tests, mounding in the downgradient direction decreased with distance from the injection well from OS 5S (4.77 feet) to OS 25S (3.57 feet). Hydraulic connectivity between the PWR and overburden was demonstrated again in the step test with PWR wells displaying an increase in water elevation varying from 1.92 to 2.76 feet.

In conclusion, the maximum flow rate that could be used for injection into the overburden while maintaining proper distribution patterns and minimizing mounding was determined to be less than 2.5 gpm. Due to the reactive nature of persulfate chemistry and the health hazard posed by the activation chemicals, a conservative flow rate of 2.0 gpm was chosen for chemical oxidation pilot study injections in the overburden. The overburden step tests also demonstrated that there was hydraulic connectivity between the overburden and the PWR during injection into the overburden.

5.3 Area of Influence Test

The area of influence test described in the Pilot Test Work Plan was not performed due to data acquired during the overburden step tests. In all step tests, each observation well in the overburden displayed sustained mounding throughout the test, indicating that the each well was being influenced by the injection. Furthermore, OS 25S demonstrated significant mounding although it was the least likely well to be influenced due to its distance from the injection point. Using a conservative approach to the overburden step test data, the area of influence is an ellipse approximately 25-30 feet along the primary axis that extends at least five feet in the upgradient direction with a secondary axis of 12 to 15 feet.

6.0 EVALUATION OF PWR ZONE INJECTION PARAMETERS

6.1 Evaluation of Fracture Orientation

A first order fracture trace analysis (referred to herein without respect to linear feature length as lineament analysis) was completed based on the topographic contour map of the Spartanburg area. As a first approximation, this interpretation provided a backdrop on which to base the surface geophysical survey. It has been documented that throughout the Piedmont physiographic province, the drainage pattern is most likely structurally controlled. Therefore, both the groundwater and surface water flow directions generally follow the structural strike orientation of the lineaments in the area. The preliminary lineament analysis was combined and augmented using digital elevation model (DEM) and aerial photograph interpretation to produce a statistically valid sample set that can be subsequently plotted as a stereonet. Based on the observation of lineaments in the area, it appears that the primary fracture orientation is along an azimuth of 322° (N38°W) with its fracture pair of 51° (N51°E) as indicated in Figure 14. Other orientations include 74°, 89°, 105°, 118°, and 316°.

Because of the difficulty in distinguishing lineaments that indicate underlying water-bearing zones, the lineament analysis was supplemented with a surface geophysical survey using spontaneous potential (SP). SP is a passive method, which measures the differences in naturally occurring electrical potentials between two points on the surface where porous-tipped electrodes have been placed. One source of these spontaneous potentials is the "streaming potential" (or electrokinetic potential) which arises from the flow of fluid (e.g., groundwater) through a porous medium. Potentials may range anywhere from 1 millivolt (mV) to over 1 volt and can be either positive or negative values.

The SP readings were acquired at 5-foot stations. Attempts were made to align the survey lines at right angles to the northwest- and northeast-striking structures identified during lineament analysis. The actual survey line orientations were adjusted in the field based on accessibility and to avoid interference from features such as overhead power lines and underground utilities (Figure 15). As indicated in Figure 15, electrodes were located past the top of the creek bank for the survey. However, placement of electrodes into the soil of the creek bank did not result in any significant disturbance since their placement simply involves pushing a limited diameter probe (similar to a garden watering bulb) into the upper soils. There was not any intrusion into the creek. Appendix C contains the field data records of the SP survey. The SP anomalies correlated well with each other, indicating fractures striking approximately N45^{o}W and N37^{o}E.

By combining the fracture trace analysis and surface geophysics, it was possible to determine the location of water bearing fractures on the Site which correspond to the most likely transmissive zones in which to direct injections. In order for injection to be successful, the degree of hydraulic interconnectivity between these fractures/ channels must be determined.

Aquifer tests were performed to evaluate the hydraulic connection between the injection well and the observation wells. The PWR injection point was installed into a water bearing fracture as identified by the geophysical survey. Subsequently, the first observation well was drilled a specified distance away from the injection point along a fracture orientation identified in the geophysical survey, and a temporary casing was installed to keep the overburden soils from collapsing into the open borehole. A water level meter was deployed in the open borehole at the intersected fracture. The aquifer test was conducted by pumping water from one well at a steady rate, while carefully measuring the water level in the other well. Mounding, or lack thereof, was used to identify transmissive fractures or geologic units open in the borehole that could act as conduits for cross-flow. This methodology was used across several borings along a given orientation to verify cross-hole connections. Once the fractures were determined to be connected to the injection point or adjacent well, the screened interval of the observation wells was installed crossing the fracture zone. By combining multiple methods, the resultant injection well field was oriented near the primary fracture set that governs the Site. Aquifer testing results suggested hydraulic communication exists between all wells. This allows for a more precise distribution of chemical treatment into the subsurface.

6.2 PWR Injection and Observation Well Installation

One Class VA-I injection well and six (6) observation wells were drilled, installed, and developed as described in Section 5.1. The locations of the injection and observation wells are shown on Figure 16.

Borings were advanced from the ground surface using HSA drilling methods. A nominal 8-inch OD X 4.25-inch ID borehole was advanced to the top of bedrock. The PWR injection well (IR) is screened from approximately 20 to 25 feet bgs. The PWR observation wells (OR) are generally screened between 20 to 25 feet bgs depending on refusal. Well identification numbers for the PWR monitoring wells are: OR 3S, OR 5S, OR 10S, OR 3W, OR 5W, and OR 10W. Well identification numbers indicate the direction and approximate distance from the injection well (i.e., OR 3W is 3 feet west of the injection well). Drilling wastes (cuttings and development water) were collected and placed in drums for off-site disposal. Figure 17 provides a cross section for the PWR injection and observation points.

6.3 Step Injection Test

6.3.1 PWR Step Test Methods

An injection step-rate test was conducted to determine sustainable injection rates in the PWR for full-scale remedial injection design. The flow rates for the PWR step tests were based on a flow rate of 2 gpm determined in overburden step tests (Table 6). Flow rates in the PWR were expected to be less than 2 gpm due to the less permeable nature of the matrix relative to the overburden. The injection pressure was held at an average pressure of 5 to 10 psi. Maximum permissible mounding was defined as 3 feet for PWR step injection tests.

Table 6. PWR Injection Step Test Parameters

Test Number	Flow Rate (gpm)	Pressure (psi)	Injection Volume (gallons)
1	1.0	5-10	180
2	2.0	5-10	360

gpm = gallons per minute
psi = pounds per square inch
PWR = partially weathered rock

The PWR step tests were conducted utilizing the same methods as the overburden step test described in Section 5.2. The injection test was monitored via observation wells with electronic pressure transducers/conductivity probes (In-Situ Aqua Troll 200s or equivalent) installed along two axes (conjugate fracture pair) from the injection well as shown on Figure 16. The step injection test was a one-time event conducted over two days to determine in-situ subsurface hydraulic properties to develop injection parameters to be used in the ISCO pilot study. After completion of each injection rate test, a sufficient time for relaxation of any mounding (return to within 10% to 15% of baseline) will be allowed before beginning the next step of the test. Water elevation data from each transducer was plotted versus time and segregated by step test as shown in Appendix B.

6.3.2 Step Injection Test Results

PWR step test 1 had a flow rate of 1 gpm, pressure of 5-10 psi, and a total volume of 180 gallons. Mounding in the PWR observation wells varied from 0.57 feet (OR 10S) to 2.06 feet (OR 3S), and decreased with distance from the injection well on both axes. The water elevation in the PWR wells increased as a step function upon initiating of the injection, and subsequently continued to increase along a moderate slope as the injection progressed. The observation wells recovered to baseline levels in approximately 200 minutes in a logarithmic manner. Mounding along the two axes was comparable in the conjugate well pair nearest the injection well with OR 3S (2.06 feet) and OR 3W (2.04 feet). The west axis displayed higher mounding than the south at well pairs 5 feet and 10 feet from the injection well. Well OR 5W mounded to 1.63 feet, which was larger than the mounding observed in OR 5S (0.95 feet). Mounding at OR 10W (1.33 feet) was significantly greater than mounding at OR 10S (0.57 feet). Additionally, OR 5S and OR 10S displayed a more linear increase in their water elevations in contrast to the rapid rise seen at the beginning of injection at the other PWR observation wells.

The higher degree of mounding along the west axis could be due to better hydraulic communication along the fracture that the observation well and the injection well are screened in or that the fracture aperture is larger to the west as compared to the south. West observation wells are located along the trend of the dominant set of vertical fractures, when viewed from the injection well. The south observation wells are perpendicular to the dominant set and parallel to the secondary set. Transmissivity is expected to be greatest largest parallel to the principal set of fractures. Mounding in the overburden was observed in this PWR step test, demonstrating the hydraulic connectivity between the two zones. The largest magnitude of mounding occurred at OS 10S (1.52 feet) located adjacent to the south axis PWR observation wells. The smallest degree of mounding in the overburden observation wells was observed at OS 10E (0.35 feet), which is the furthest overburden well from the PWR injection well. The water elevations in the overburden wells changed in the same pattern as the PWR wells, but did not recover to baseline levels until 500 minutes after the injection ceased.

PWR step test 2 had a flow rate of 2 gpm, pressure of 5-10 psi, and a total volume of 360 gallons. The flow rate for step test 2 was increased to 2.0 gpm to establish the upper bound of acceptable injection flow rates for the PWR. Mounding in the PWR observation wells varied from 0.81 feet at OR 10S to 3.12 feet at OR 3W and decreased with distance from the injection well on both axes. Mounding greater than or near the acceptable maximum of 3 feet occurred at OR 3S (2.89 feet), OR 3W (3.12 feet), and OR 5W (2.86 feet). The mounding and recovery pattern for the PWR wells was the same as in step test 1, requiring approximately 500 minutes before recovering to baseline levels. The change in water elevation observed during injection was significantly higher in the west axis than the south axis, with OR 5W (2.86 feet) compared to OR 5S (1.52 feet). The same pattern was observed at increased distance from the injection point at OR 10W (2.46 feet) relative to OR 10S (0.81 feet). This further demonstrates the fracture dominated anisotropy of the PWR aquifer with preferential flow to the west. Mounding in the overburden observation wells ranged from 0.82 feet (OS 10E) to 1.88 feet (OS 15S) in this PWR step test, further demonstrating the interconnectivity between the bedrock and the overburden.

In conclusion, the maximum flow rate selected for pilot injection into the PWR to minimize mounding was determined to be less than 1.0 gpm. Mounding observed while injecting at a flow rate of 1.0 gpm in step test 1 was less than the acceptable maximum of 3 feet, but a more conservative flow rate of 0.5 to 0.75 gpm was chosen for the pilot study injections as a safety precaution due to the reactive nature of persulfate chemistry and potential for pressure build up in the PWR as contaminants are mineralized.

6.4 Area of Influence Test

The area of influence test described in the Work Plan was not performed due to data acquired during the PWR step tests. In both step tests, each observation well in the PWR displayed sustained mounding throughout the test, indicating that the each well was being influenced by the injection. The step tests also demonstrated that the west axis observation wells were better connected to the fracture that the injection well intercepted than the south axis wells. Influence from the injection was still observed in the south axis observation wells.

7.0 PILOT ISCO INJECTION FOR THE SHALLOW ZONE

7.1 Shallow Zone ISCO Injection Zone Process and Conditions

7.1.1 Shallow Zone ISCO Injection Loading

The shallow zone ISCO pilot test consisted of injecting sodium persulfate solution into the groundwater in the vicinity of the MW-13 well cluster to mineralize dissolved BTEX, PAHs, and TPH. Based on the results of the injection step tests, the injection area of influence was anticipated to be between 800 and 950 ft^2. Groundwater in the pilot test area was monitored prior to, during, and following the four weeks of injections. Post-injection sampling (discussed in more detail in Section 7.2) was conducted to monitor parameters indicative of oxidation, confirm the effectiveness of the sodium persulfate dosage design, monitor for potential impact to Chinquapin Creek, and monitor for increases in metals concentrations resulting from the oxidizing conditions and changes in pH. Results of performance monitoring during this phase was used to refine the implementation of subsequent injection phases and to design the injection program for full-scale implementation.

During installation of the observation wells in late September 2012, soil samples were collected from the borings for wells OS 5S, OS 10S, OS 20S, and soil boring SOD-4. These data were previously presented in Section 4.1. Soil concentrations of BTEX, alkyl benzenes, and TPH-GRO were 5 to 10 times greater than the initial estimates used to estimate loading for the *Chemical Oxidation Pilot Test Work Plan.* Concentrations of naphthalene, several other PAHs, and TPH-DRO were also several times greater than the initial estimates used as the basis of loading in the Work Plan. Groundwater samples were also collected from the shallow observation wells in the pilot study area during the first week of October 2012. BTEX and light hydrocarbon concentrations similar to historic results at MW-13S, but PAH and TPH-DRO concentrations in groundwater from these wells were several times greater than previously estimated from historic data. Based on the data obtained during installation of the Pilot Study wells, the total mass of hydrocarbons in the pilot area was estimated at approximately 350 lbs.

The stoichiometric demand for oxidant was determined from the estimated hydrocarbon mass derived from the data obtained during installation of the Pilot Study area injection wells. SOD was estimated from the test data previously presented in Section 4.2 to be 360 lbs, yielding a total oxidant demand of 17,760 lbs. The persulfate was blended as a 20% solution for injection yielding an injection volume of 9,260 gallons.

Activator demand is directly related to the mass of oxidant and soil buffering capacity. Soil buffering capacity data were previously presented in Section 4.2. Based on that data, approximately 2,400 gallons of 25% sodium hydroxide was required. The sodium hydroxide was injected as a 25% solution requiring a total of 2,390 gallons.

In order to provide good distribution of the reagents in the aquifer and avoid issues related to surfacing of reagents or development of preferential pathways, the total volume of 12,360 gallons of reagents was injected in four separate events of approximately four days duration each. For each separate event, one fourth of the total reagent volume (approximately 3,000 gallons) was injected at a flow rate of 2 gpm or less.

7.1.2 Shallow Zone ISCO Injection Zone Process

Figure 18 provides a process instrument diagram for the mixing and injecting process. Potable water was obtained from an off-site fire hydrant and temporarily stored in a water truck. Sodium persulfate was transferred from 55-lb bags and mixed with the potable water in the persulfate mix tank (T2) to form a 20% solution. The potable water was transferred to the mix tank from the water truck using an electrical powered centrifugal pump (P1). The solution was mixed using a centrifugal pump (P2) connected by rubber hose and camlock fittings to a mixing rod that has a nozzle on the end. The 20% solution was transferred to persulfate blend tank (T1) by a centrifugal pump (P2). A portion of the flow from Tank T1 was continually re-circulated to ensure uniform mixing. The 20% persulfate solution was subsequently pumped to the injection well by an electrical powered multi-stage centrifugal pump (IP1) at 1.6 gpm. The flow to the injection well was controlled by a globe valve, and the flow rate and total volume injected was recorded by a digital flow totalizer. Delivery pressure of the injectant was controlled by a pressure regulating valve located downstream of the flow totalizer.

The 25% sodium hydroxide solution was pumped directly from the chemical tote to the injection well by electrical powered metering pump at 0.4 gpm. The flow rate from the metering pump was controlled by the variable drive integral to the pump. The flow rate and total volume injected were recorded by a digital totalizer and delivery pressure of the injectant was controlled by a pressure regulating valve.

The injection well-head assembly had separate inlets for each solution with the inlets isolated from one another by check valves. Mixing of the two reagents occurred in the injection well head to ensure contact between the two solutions and effective generation of sulfate radicals.

Pilot injections for the overburden were conducted as four separate injection events. The first three events were completed in December 2012 and the fourth event was conducted the week of January 7, 2013. Table 7 summarizes the injection volumes for each of the four events.

Table 7. Summary of Shallow Pilot Injection Volumes

Date	Sodium Persulfate Solution Injected (gallons)	Sodium Hydroxide Injected (gallons)
12/4/2012	740	110
12/5/2012	760	114
12/6/2012	350	216
Week 1 Total	*1,850*	*440*
12/10/2012	370	89
12/11/2012	740	203
12/12/2012	743	185
12/13/2012	751	189
12/14/2012	385	98
Week 2 Total	*2,989*	*764*
12/17/2012	375	95
12/18/2012	760	260
12/19/2012	750	109
12/20/2012	460	115
Week 3 Total	*2,345*	*579*
1/7/2013	200	87
1/8/2013	700	201
1/9/2013	930	233
1/10/2013	490	60
Week 4 Total	*2,320*	*581*
Grand Total	**9,504**	**2,364**

Groundwater parameters were measured in the shallow observation wells periodically during injection to monitor the effectiveness and distribution of the injected reagents. The following groundwater quality parameters were measured using the Yellow Springs Instruments (YSI) Model 5620 by placing the instrument down the well in the middle of the screened interval: pH, specific conductance (microsiemens per centimeter [μS/cm]), temperature (degrees Celsius [°C]), oxidation reduction potential (ORP) (mV), and dissolved oxygen (DO) (mg/L). The groundwater geochemical parameters monitored during injection are included in Appendix D.

Measurements were also taken at least daily from Chinquapin Creek at the creek bank south of the pilot area and from the bridge located upstream. The values were compared to one another to ensure the injected chemicals were not impacting the creek. The water quality parameters measured in the stream immediately adjacent to the pilot area remained consistent with parameters measured upstream throughout all of the shallow zone injections. This monitoring data indicated that the area of influence of the injection was sufficiently set back from the stream so that the injected chemicals did not reach Chinquapin Creek.

Increases from baseline conditions in the geochemical parameters: temperature, ORP, and DO indicate that oxidative conditions had occurred. Since ISCO chemistry is an exothermic reaction, an increase in groundwater temperature from baseline conditions could be used to monitor if the reaction is occurring. The ORP of water is a measure of its tendency to undergo either reductive or oxidative reactions. A positive ORP indicates that an oxidative environment is occurring. Aqueous oxidation reactions produce oxygen molecules, thus an increase in DO in the aquifer would indicate that an oxidative reaction is occurring.

Distribution of the alkaline injection fluid was best tracked by the monitoring of pH in the observation wells because an increase in pH in an observation well indicated that the solution had influenced that area. Monitoring pH was also necessary for adjusting dosing of the sodium hydroxide since a sustained aquifer pH of 10.5 SU or greater is required for alkaline activated sodium persulfate, but too great of an increase could result in prolonged change in the aquifer pH.

7.1.3 Shallow Zone ISCO Injection Zone Conditions

Week 1 Injection – December 4, 2012

Prior to the first week of injection activities, AMEC constructed the injection system and took delivery of the chemicals needed for the shallow zone injection and securely stored them behind a locked chain linked fence.

Initial geochemical parameters in the shallow observation wells were generally as follows: specific conductivities of 0.3-0.4 (μS/cm), slightly negative ORP values (-30 mV), neutral to slightly acidic pH values of approximately 6.3 SU, DO values <1.0 mg/L, and temperatures of approximately 18°C.

Changes in the geochemistry due to the first week of injections were limited to observation wells located 10 feet or less from the injection well. OS 5N, OS 10E, OS 5S, and OS 10S all experienced a slight rise in conductivity and ORP. In OS 5N, ORP rose significantly from -13.50 to 185 mV. Measured pH values did not change significantly because the natural buffering capacity of the soil and groundwater had not yet been overcome.

Week 2 Injection – December 10, 2012

Significant changes in the geochemistry after the second week of injections were observed in observation wells located 10 feet or less from the injection well. At upgradient well OS 5N, ORP increased from its baseline condition of -13.50 to 275 mV. Observation wells OS 5E and OS 10E in the cross-gradient direction experienced a large increases in pH, ORP, and DO. At the end of the second week of injection, pH values were 13.05 SU (OS 5E) and 9.19 SU (OS 10E). At OS 5E, both ORP (254 mV) , and DO (6.08 mg/L) were elevated. At OS 10E, ORP (309 mV) was more elevated that at OS 5E and DO was similar to the well nearest the injection point.

Observation wells OS 5S and OS 10S exhibited significant increases in ORP, pH, DO, and temperature. ORP increased from baseline conditions of 34.8 to 229 mV in OS 5S, and from -7.0 to 240 mV in OS 10S. Values of pH increased from 6.5 in both wells to 10.25 in OS 5S and 7.06 in OS 10S. A significant increase in DO was also exhibited at these wells with an increase from less than 1 mg/L to approximately 9 mg/L. The 5°C temperature increase observed at the end of the second week was a strong indication that oxidation of the MGP contaminants was occurring.

Both DO and ORP had increased significantly at OS 15S at the end of the second week of injection. Changes in pH were not evident at this distance at this time since residual soil acidity had not been overcome. Notable changes in geochemical parameters had not occurred at the monitoring points farther downgradient as of the second week of injection.

This data indicated that after two weeks of injection, an oxidative environment was created by the injections in area at least 5 feet upgradient, 10 feet cross gradient, and 10 feet downgradient from the injection well. This area also had values of pH greater than 10.5 SU, indicating that the persulfate activation and free radical generation was being achieved.

Week 3 Injection – December 17, 2012

At the end of the second week, evaluation of the data suggested that residual soil acidity was somewhat greater than determined by the soil buffering demand test performed in the laboratory. Therefore in the third week, approximately 40 gallons of sodium hydroxide was injected daily before the injection of both sodium persulfate and sodium hydroxide. This approach was used to create an alkaline lead front that significantly reduced soil residual acidity to allow the pH in downgradient wells to reach a level of 10.5 SU needed for activation.

Geochemical parameters for the observation wells influenced by the previous week's injections indicated more robust oxidative conditions and a rise in pH as the injection progressed in the third week. At OS 5E; OS 5S; and OS 10S, pH remained elevated or rebounded to levels above those observed at the end of the second week of injection. The mean ORP for the five wells within 10 feet of the injection point was 145 mV on the second day of the week and had reached 227 mV by the end of the week.

Geochemical parameters at observation wells OS 15S, OS 20S, and OS 25S had not previously exhibited any significant changes in the first two weeks of injection. At the end of the third week, changes in ORP, pH, and DO were evident at these wells signifying that entire estimated treatment area had been influenced by the injections. At well OS 15S changes in pH and DO were not significant, but ORP increased from -10.2 to 95.96 mV. The reduced influence of the injections at well OS 15S is believed to result from differences in soil particle size or the presence of microfractures in the vicinity of this well relative to the other monitoring points that locally reduced reagent flow to the vicinity of this well.

Well OS 20S exhibited significant increases from baseline conditions in conductivity, ORP, and pH. Conductivity increased from 0.519 to 115.7 µS/cm, while ORP increased from -9.5 to 164.5 mV. The strongest indicator that the injections influenced the area around OS 20S was the rise in pH from 7.34 to 13.13 SU.

The furthest downgradient observation well from the injection point (OS 25S) exhibited geochemical changes by the end of the third week of activities. Conductivity, ORP, and pH increased significantly from baseline conditions. Conductivity increased from 0.33 to 71.93 µS/cm, while ORP increased from -48.9 to 212.3 mV. Values of pH increased from 6.27 to 10.40 SU near the activation limit.

At the conclusion of the third week of injections, every observation well (except OS 15S) in the shallow zone was displaying geochemical changes representative of an oxidative environment and had a pH greater than or near 10.5 SU.

Week 4 Injection – January 7, 2013

Due to pH values receding since the previous injection, approximately 40 gallons of sodium hydroxide was injected daily before the injection of both sodium persulfate and sodium hydroxide began. By the third day of injections, pH values had recovered in most wells to greater than 10.5 SU because the natural buffering capacity of the soil had been consumed by previous injections. Geochemical conditions indicative of an oxidative environment were observed in all shallow observation wells.

At both OS 5E and OS 5S, pH exceeded 12 SU and ORP was above 300 mV. DO levels were also very elevated at these wells. Well OS 10E had previously displayed pH values as high as 12.4 SU, but only reached a high of 8.38 SU. ORP remained highly positive, indicating that the area in the vicinity of this well was still undergoing oxidation.

The impact of the temporary cessation of the injections over the holidays was most notable at the most downgradient observation points. At well OS 15S, ORP and DO did not rebound during the last week of injection. Both DO and ORP levels rebounded at OS 20S and OS 25S, but did not reach the levels observed at the end of the third week of injection.

7.2 Shallow (Overburden) Performance Monitoring

The pilot ISCO Injection for the shallow zone included seven sampling events and generated a significant amount of data. Three key components of the monitoring program were: (1) monitoring baseline conditions, (2) measuring oxidant delivery effectiveness, and (3) evaluating contaminant treatment efficacy. The pilot test results are discussed in Section 7.3 in terms of the MGP contaminants of interest, reduction-oxidation state indicators (DO and ORP) and reduction-oxidation sensitive metals. The remaining analytes, that are not indicators relative to evaluation of the technology, are included in the data tables, but not discussed. Laboratory reports are included in Appendix E. Field reports recording geochemical parameters measured as part of performance monitoring are included in Appendix F. Table 8 summarizes the baseline and performance sampling matrix for shallow (overburden) groundwater for this pilot test.

Prior to well purging, depth to water was measured to the nearest 0.01 foot at each well using an electric water-level indicator. All groundwater level measurements were made relative to an established reference point on the well casing. Groundwater monitoring wells were purged and samples collected at a low rate using a variable speed pump (peristaltic pump) following EPA low-flow sampling methods. The following groundwater quality parameters were measured using the YSI Model 6920: pH, specific conductance (µS/cm), temperature (°C), ORP (mV), turbidity (nephelometric turbidity unit [NTU]), and DO (mg/L). Collection of

Table 8. Overburden Performance Monitoring Network and Parameters

MONITORING NETWORK AND PARAMETERS				
Frequency	**Monitoring Wells**	**Quality Control Samples**	**Parameter**	**Analytical Method**
Baseline *(October 4-5, 2012)*	MW-13S, MW-13D, MW-13 ISOC Overburden Observation Wells* PWR Observation Wells**	(3) Trip Blanks (1) Duplicate	VOCs SVOCs Sulfate TPH Metals	Method 8260B Method 8270C Method 9056 Method 8015B-PHI Method 6010B or Method 6020
OVERBURDEN INJECTION MONITORING				
Frequency	**Monitoring Wells**	**Quality Control Samples**	**Parameter**	**Analytical Method**
Overburden Injection: Weeks 1 & 3 *(January 18 , 2013 & January 28, 2013)*	OS-5N OS-5E, OS-10E OS-5S, OS-10S, OS-15S, OS-20S, OS-25S OR-3S[1], OR-5S[1] OR-3W[1], OR-5W[1], OR-10W[1]	NA	Persulfate pH, DO, ORP specific conductance turbidity	Klozur® persulfate field test kit (1/18/2013) Hach persulfate field test kit (1/28/2013) YSI Model 6920 or equivalent YSI Model 6920 or equivalent YSI Model 6920 or equivalent
Overburden Injection: Weeks 2 & 4 *(January 23, 2013 & February 4, 2013)*	OS-5E, OS-10E OS-5S, OS-10S, OS-15S, OS-20S, OS-25S OR-5S[1], OR-5W[1], OR-10W[1] MW-13 ISOC	(4) Trip Blanks	VOCs SVOCs Sulfate TPH Metals	Method 8260B Method 8270C Method 300.0 Method 8015B-PHI Method 6010B or Method 6020

Table 8. Overburden Performance Monitoring Network and Parameters (Continued)

OVERBURDEN INJECTION MONITORING				
Frequency	**Monitoring Wells**	**Quality Control Samples**	**Parameter**	**Analytical Method**
Overburden Injection: Week 5 *(February 12, 2013)*	OS-5N	NA	Persulfate	Klozur® persulfate field test kit
	OS-5E, OS-10E		pH, DO, ORP	YSI Model 6920 or equivalent
	OS-5S, OS-10S, OS-15S, OS-20S, OS-25S		specific conductance	YSI Model 6920 or equivalent
	OR-5S[1], OR-5W[1], OR-10W[1]		turbidity	YSI Model 6920 or equivalent
Overburden Injection: Week 6 *(February 18, 2013)*	OS-5N	NA	pH, DO, ORP	YSI Model 6920 or equivalent
	OS-5E, OS-10E		specific conductance	YSI Model 6920 or equivalent
	OS-5S, OS-10S, OS-15S, OS-20S, OS-25S		turbidity	YSI Model 6920 or equivalent
	OR-3S[1], OR-5S[1], OR-5W[1], OR-10W[1]			
Semi-annual Event: Week 7 *(February 27-28, 2013)*	Semi-annual Network Wells***	(3) Trip Blanks	VOCs	Method 8260B
		(1) Duplicate	SVOCs	Method 8270C
			Metals	Method 6010B or Method 6020
			TPH	Method 8015B-PHI

* Overburden Observation Wells – OS-5N, OS-5E, OS-10E, OS-5S, OS-10S, OS-15S, OS-20S, OS-25S

** PWR Observation Wells – OR-3W, OR-5W, OR-10W, OR-3S, OR-5S, OR-10S

*** Semi-annual Network Wells – Overburden: MW-1SS, MW-2SS, MW-3SS, MW-10S, MW-11S, MW-12S, MW-13S, MW-14S, MW-15S, MW-16S, MW-17S, MW-18S, MW-19-S; Bedrock: MW-10D, MW-11D, MW-12D, MW-13D, MW-14D, MW-15D, MW-16D, MW-18D, MW-1DR; PWR: MW-13 ISOC

[1] Field water quality parameters only (pH, DO, ORP, specific conductance, temperature, turbidity)

Notes: DO = dissolved oxygen
NA = not applicable
ORP = oxidation-reduction potential
PWR = partially weathered rock
SVOC = semivolatile organic compound
TPH = total petroleum hydrocarbons
VOC = volatile organic compound

groundwater samples commenced after purging. Groundwater samples were collected directly into laboratory-supplied sample containers from the pump discharge. Groundwater samples were analyzed for VOCs (EPA Method 8260B), SVOCs (EPA Method 8270C), sulfate (EPA Method 300.0), metals (EPA Method 6010), and TPH (EPA Method 8015). Samples were not filtered in the field.

Monitoring to evaluate the performance of the ISCO injection consisted of two types: contaminant monitoring and geochemical monitoring. For contaminant monitoring, groundwater samples were collected from pilot observation wells and sent to a fixed laboratory for analysis of the Site contaminants of concern including VOCs, SVOCs, sulfate, metals, and TPH. One round was performed approximately 2 weeks after injection, a second round of samples was collected approximately 4 weeks after injection, and the third round was collected approximately 7 weeks after injection to evaluate potential rebound of contamination and prior to the PWR injection. Geochemical monitoring consisted of measurement of field geochemical parameters (pH, ORP, DO, specific conductance, turbidity, and temperature) and collection of a grab sample for field analysis of persulfate. Geochemical monitoring was performed at a higher frequency than contaminant monitoring to evaluate the persistence and distribution of the injected persulfate and temporal trends in aquifer geochemistry in the pilot test monitoring wells. Geochemistry performance monitoring was performed prior to injection (baseline) and approximately 1 week, 3 weeks, 5 weeks, and 6 weeks after injection. Field analysis of persulfate concentrations were collected using a Klozur® or Hach persulfate field test kit.

7.3 Shallow (Overburden) Results

7.3.1 Baseline Conditions

Prior to performing any injections, samples were collected from select monitoring wells to evaluate baseline VOC, SVOC, metals, sulfate, and TPH concentrations in groundwater. Between October 3-5, 2012, AMEC personnel conducted the baseline groundwater sampling event for the set of parameters specified in the Work Plan. These parameters establish the ambient baseline concentrations within the pilot study treatment area and provide the mechanism to evaluate the effectiveness of the pilot test. Seventeen groundwater wells were sampled in one round of pre-injection groundwater sampling. Of those 17 wells, 3 downgradient monitoring wells (MW-13S, MW-13D, and MW-13 ISOC), 8 shallow (overburden) wells, and 6 PWR wells were included.

The results for the field measured parameters (DO, ORP, and pH) are provided in Table 9. Concentrations of VOCs, TPH-GRO are provided in Table 10. Baseline monitoring data for SVOCs and TPH-DRO are provided in Table 11. Baseline sampling results for metals and sulfate are provided in Table 12.

Table 9. Results for Geochemical Parameters – Overburden Performance Monitoring

Well Number	Date Sampled	Temp (°C)	Specific Conductance (μS/cm)	pH	Turbidity (NTU)	ORP (mV)	DO (mg/L)	Persulfate (g/L)
OS-5N	10/05/12	23.42	0.964	6.22	6.7	-45	0.00	NM
	01/18/13	21.14	26.250	9.68	257.0	221	4.12	44.00
	01/23/13	20.00	25.700	9.55	162.0	396	0.84	NM
	01/28/13	16.09	7.870	5.55	16.9	278	2.69	8.50
	02/04/13	16.13	8.670	5.46	372.0	223	0.22	NM
	02/12/13	18.06	6.670	5.43	27.4	194	4.39	8.50
	02/18/13	18.91	9.410	5.86	47.1	310	1.75	NM
	02/28/13	14.52	2.060	5.97	42.8	140	3.25	0.07
OS-5S	10/05/12	22.63	0.784	6.11	7.7	-18	0.56	NM
	01/18/13	23.35	25.030	9.56	86.8	239	8.13	44.00
	01/23/13	18.49	48.500	8.41	78.5	238	4.32	NM
	01/28/13	16.08	47.200	6.53	14.6	397	6.13	47.00
	02/04/13	18.10	70.800	6.59	97.0	315	2.85	NM
	02/12/13	17.35	72.400	6.70	28.7	236	2.36	44.00
	02/18/13	18.29	32.400	10.15	124.0	232	8.60	NM
	02/28/13	15.28	37.400	8.32	98.7	224	14.75	0.07
OS-5E	10/05/12	23.88	0.742	6.08	6.2	70	1.52	NM
	01/18/13	18.93	27.390	12.39	3.7	60	23.20	44.00
	01/23/13	17.38	13.700	11.53	20.1	-27	26.61	NM
	01/28/13	15.01	9.240	10.22	18.1	48	37.49	14.50
	02/04/13	16.84	9.620	9.54	14.1	154	27.76	NM
	02/12/13	16.83	16.800	7.67	21.1	165	23.10	23.50
	02/18/13	19.19	5.110	8.46	23.8	186	19.62	NM
	02/28/13	13.03	2.980	6.79	24.7	137	16.97	0.07
OS-10S	10/05/12	22.46	0.593	5.81	8.4	-56	0.35	NM
	01/18/13*	19.10	0.597	6.60	49.6	91	5.10	5.50
	01/23/13	15.73	9.770	5.81	22.3	228	19.60	NM
	01/28/13	16.31	12.900	5.95	12.2	379	7.12	29.50
	02/04/13	15.23	23.900	5.42	45.8	187	7.45	NM
	02/12/13	16.11	11.900	5.57	38.4	87	0.00	20.00
	02/18/13	17.18	8.040	5.38	42.1	178	4.58	NM
	02/28/13	15.87	7.490	6.28	18.2	119	0.00	0.07

Table 9. Results for Geochemical Parameters – Overburden Performance Monitoring (Continued)

Well Number	Date Sampled	Temp (°C)	Specific Conductance (μS/cm)	pH	Turbidity (NTU)	ORP (mV)	DO (mg/L)	Persulfate (g/L)
OS-10E	10/05/12	23.58	0.575	6.36	9.8	-44	0.18	NM
	01/18/13*	16.85	0.928	9.19	6.1	408	2.37	8.50
	01/23/13	16.41	3.910	6.90	19.9	226	0.98	NM
	01/28/13	14.93	0.682	6.72	14.6	111	0.59	2.50
	02/04/13	15.31	0.730	7.07	22.1	179	0.00	NM
	02/12/13	16.34	2.040	7.16	21.4	122	0.54	20.00
	02/18/13	19.53	1.090	6.91	25.1	155	1.73	NM
	02/28/13	10.68	0.474	6.99	23.4	96	0.47	0.014
OS-15S	10/04/12	29.91	0.565	5.78	9.5	93	0.21	NM
	01/18/13*	18.52	0.557	6.62	19.8	76	18.52	2.50
	01/23/13	14.10	0.354	6.23	58.0	111	0.85	NM
	01/28/13	15.92	2.210	6.42	42.9	276	0.00	5.50
	02/04/13	14.23	0.310	6.62	25.5	61	0.00	NM
	02/12/13	15.29	0.313	6.54	40.7	-2	0.00	17.50
	02/18/13	16.59	0.296	6.49	51.7	21	7.54	NM
	02/28/13	14.83	0.535	7.11	48.2	68	5.11	0.0021
OS-20S	10/05/12	20.66	0.590	6.30	9.7	-74	0.02	NM
	01/18/13*	16.49	0.503	6.48	9.8	153	5.51	2.50
	01/23/13	12.60	2.190	6.31	111.0	137	22.83	NM
	01/28/13	15.48	0.821	6.47	14.3	263	8.27	2.50
	02/04/13	13.52	0.832	6.56	139.0	14	0.00	NM
	02/12/13	14.45	0.687	6.54	23.1	-35	0.00	5.50
	02/18/13	16.58	0.456	6.62	1.9	-10	6.00	NM
	02/28/13	13.53	0.449	6.56	31.2	74	2.65	0.035
OS-25S	10/05/12	20.57	0.508	6.22	7.7	-51	2.18	NM
	01/18/13*	16.29	8.003	3.95	29.8	343	0.43	2.50
	01/23/13	11.85	8.890	6.97	9.4	17	0.00	NM
	01/28/13	14.42	2.150	5.15	11.8	59	2.69	2.50
	02/04/13	13.27	3.890	4.21	14.7	88	0.00	NM
	02/12/13	14.12	1.180	5.49	3.8	-17	0.00	2.50
	02/18/13	17.63	0.799	5.51	1.4	-8	0.00	NM
	02/28/13	14.31	0.785	5.31	26.9	62	0.89	0.06

Table 9. Results for Geochemical Parameters – Overburden Performance Monitoring (Continued)

Well Number	Date Sampled	Temp (°C)	Specific Conductance (μS/cm)	pH	Turbidity (NTU)	ORP (mV)	DO (mg/L)	Persulfate (g/L)
OR-3S	10/04/12	21.96	0.688	5.93	8.7	-427	0.00	NM
	01/18/13*	18.55	0.771	6.93	6.2	105	0.43	NM
	01/28/13	16.90	0.701	6.54	7.0	20	0.00	NM
	02/12/13	15.08	0.556	7.30	5.7	164	4.18	NM
	02/18/13	18.02	0.444	7.42	1.8	84	7.74	NM
	02/28/13	20.11	2.330	6.90	23.9	204	0.00	NM
OR-3W	10/04/12	21.09	0.671	6.03	9.9	-453	0.16	NM
	01/18/13*	18.06	0.386	7.58	10.4	114	4.51	NM
	01/28/13	16.89	4.670	6.35	8.0	126	0.00	NM
	02/28/13	12.26	7.760	6.10	2.8	248	1.38	NM
OR-5S	10/04/12	21.92	0.640	6.03	9.6	221	5.50	5.50
	01/18/13*	18.19	0.406	6.69	16.9	93	0.71	NM
	01/23/13	12.60	0.769	6.05	11.2	147	1.11	NM
	01/28/13	15.94	0.499	6.77	23.3	27	6.03	NM
	02/04/13	14.51	0.661	6.91	6.7	183	4.49	NM
	02/12/13	15.47	0.411	7.14	3.1	163	2.90	NM
	02/18/13	17.92	0.369	7.10	1.2	98	7.08	NM
	02/28/13	18.39	0.397	6.69	2.4	92	2.43	NM
OR-5W	10/04/12	20.83	0.689	6.45	8.4	-176	4.71	NM
	01/18/13*	17.31	0.423	7.48	2.8	98	4.57	2.50
	01/23/13	7.84	3.170	5.67	6.5	199	2.47	NM
	01/28/13	16.45	1.500	6.94	7.6	106	2.81	NM
	02/04/13	14.33	3.370	5.93	12.3	236	6.64	NM
	02/12/13	14.08	1.970	6.60	5.0	195	4.06	NM
	02/18/13	17.11	0.866	6.92	2.1	99	3.82	NM
	02/28/13	14.60	3.710	5.84	9.8	258	0.94	NM
OR-10S	10/04/12	21.37	0.758	6.09	8.7	7	8.98	NM
	02/28/13	9.75	15.300	6.19	27.7	230	6.21	NM

Table 9. Results for Geochemical Parameters – Overburden Performance Monitoring (Continued)

Well Number	Date Sampled	Temp (°C)	Specific Conductance (μS/cm)	pH	Turbidity (NTU)	ORP (mV)	DO (mg/L)	Persulfate (g/L)
OR-10W	10/04/12	19.01	0.603	6.35	8.7	-153	0.05	NM
	01/23/13	9.67	2.590	5.90	3.6	201	1.63	NM
	01/28/13	15.65	0.496	7.16	7.5	172	4.48	NM
	02/04/13	14.27	15.400	3.93	43.8	344	0.00	NM
	02/12/13	14.65	3.060	6.05	8.2	209	0.00	NM
	02/18/13	18.28	2.780	6.09	6.2	145	0.00	NM
	02/28/13	15.84	7.720	5.84	6.2	275	1.65	NM
MW-13 ISOC	01/23/13	9.25	11.700	5.49	18.8	248	5.06	NM
	02/04/13	14.68	13.700	6.36	55.3	187	1.29	NM
	02/28/13	13.81	8.690	6.10	2.1	152	0.00	NM

* Specific conductance measurements on 1/18 were corrected to μS/cm after review of the field purge logs.

Notes: °C = degrees Celsius
μS/cm = microsiemens per centimeter
DO = dissolved oxygen
g/L = grams per liter
mg/L = milligrams per liter
mV = millivolt
NM = not measured
NTU = nephelometric turbidity unit
ORP = oxidation reduction potential

Table 10. Results for Volatile Organic Compounds – Overburden Injection Performance Monitoring

Monitoring Well	Date Sampled	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone (MEK)	Acetone	Benzene	Bromomethane	Carbon Disulfide	Chloroform	Chloromethane	Ethylbenzene	Isopropylbenzene	Methylene chloride	Naphthalene	n-Butylbenzene	n-Propylbenzene	p-Isopropyltoluene	Styrene	Toluene	Xylenes, total	Gasoline Range Organics
	RBSL	--	--	--	--	--	--	--	5	--	--	--	--	700	--	--	25	--	--	--	--	1,000	10,000	--
MW-13S	03/20/12	<5.00	<5.00	**6.75**	**83.3**	**29.9**	<250	<250	**340**	<5.00	<5.00	<5.00	<5.00	**115**	**14**	<25	**510**	<5.00	**5.45**	<5.00	<5.00	**41.4**	**100**	NA
	10/03/12	<1.00	<5.00	<1.00	**118**	**41.9**	<50.0	<50.0	**247**	<1.00	<1.00	<1.00	<1.00	**116**	**15.9**	<5.00	**714**	**9.07**	**7.58**	**4.15**	<1.00	**32.1**	**99.9**	**1,510**
	02/27/13	<20.0	<20.0	<20.0	**143**	**36.1**	<1000	<1000	**25.7**	<20.0	<20.0	<20	<20.0	**88.3**	<20.0	<100	**2,290**	<20.0	<20.0	<20.0	<20.0	<20.0	<60.0	**1,450**
MW-13D	03/21/12	**1.61**	**3.94**	<1.00	**28**	**2.84**	<50.0	<50.0	**175**	<1.00	<1.00	<1.00	<1.00	**75**	**7.21**	<5.00	**1,420**	**1.56**	**8.72**	<1.00	**29.5**	**263**	**282**	NA
	10/03/12	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	**618**
	02/27/13	**1.09**	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	**5.62**	<1.00	<1.00	<1.00	<1.00	**1.17**	<1.00	<5.00	**9.46**	<1.00	<1.00	<1.00	<1.00	**3.96**	<3.00	<100
MW-13 ISOC	03/21/12	<1.00	<1.00	<1.00	**98.9**	**30.5**	<50.0	<50.0	**618**	<1.00	<1.00	<1.00	<1.00	**63.8**	**8.68**	<5.00	**1,350**	**2.76**	**2.15**	<1.00	**19.6**	**102**	**237**	NA
	10/03/12	<1.00	<1.00	<1.00	**110**	**43.7**	<50.0	<50.0	**667**	<1.00	<1.00	<1.00	<1.00	**328**	**15.2**	<5.00	**736**	**3.66**	**6.64**	**1.59**	<1.00	**45.4**	**225**	**2,180**
	01/23/13	<1.00	<1.00	<1.00	**27.4**	**7.22**	<50.0	**261**	**457**	<1.00	<1.00	<1.00	**3.32**	**77.7**	**1.7**	<5.00	**336**	<1.00	<1.00	<1.00	**6.07**	**255**	**258**	**2,060**
	02/04/13	<1.00	<1.00	<1.00	**108**	**33.4**	<50.0	**209**	**714**	**3.14**	**1.09**	<1.00	**2.81**	**127**	**3.67**	<5.00	**1,420**	<1.00	**1.69**	**3.45**	<1.00	**453**	**542**	**3,520**
	02/27/13	<1.00	<1.00	**12**	**110**	**35.6**	<50.0	**81.4**	**495**	<1.00	<1.00	<1.00	<1.00	**129**	**3.21**	<5.00	**1,430**	**1.38**	**2.25**	**1.28**	**58.2**	**476**	**446**	**4,700**
OS 5N	10/05/12	<1.00	<1.00	<1.00	**28.1**	**8.89**	<50.0	<50.0	**3.41**	<1.00	<1.00	<1.00	<1.00	**18.7**	**4.62**	<5.00	**258**	<1.00	**2.01**	**1.26**	<1.00	<1.00	**13.4**	**246**
	02/28/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	**1.0**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
OS 5S	10/05/12	<1.00	<1.00	<1.00	**147**	**43.6**	<50.0	<50.0	**8.80**	<1.00	<1.00	<1.00	<1.00	**105**	**21.7**	<5.00	**2,660**	<1.00	**10.1**	**6.59**	<1.00	**1.74**	**80.6**	**1,600**
	01/23/13	<1.00	<1.00	<1.00	<1.00	<1.00	**285**	**2,830**	**1.27**	**44**	**1.79**	<1.00	**40.6**	**4.17**	**1.26**	<5.00	**52.8**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<500
	02/04/13	<1.00	<1.00	<1.00	<1.00	<1.00	**239**	**2,060**	<1.00	**120**	**2.86**	<1.00	**133**	**2.94**	<1.00	<5.00	**32.2**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<500
	02/28/13	<1.00	<1.00	<1.00	**3.09**	**1.13**	<50.0	**519**	<1.00	**29.8**	**1.91**	<1.00	**42.8**	**4.92**	**2.5**	<5.00	**43**	**1.05**	**1.22**	**1.19**	<1.00	<1.00	<3.00	<100
OS 5E	10/05/12	<1.00	<1.00	<1.00	**8.93**	**2.36**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	**3.2**	**1.21**	<5.00	**166**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	01/23/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**146**	<1.00	**11.1**	<1.00	<1.00	**7.88**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	02/04/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**91.3**	<1.00	**7.2**	<1.00	<1.00	**11.7**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	02/28/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	**1.73**	<1.00	<1.00	**2.48**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
OS 10S	10/05/12	<1.00	<1.00	<1.00	**114**	**37.6**	<50.0	<50.0	**4.33**	<1.00	<1.00	<1.00	<1.00	**66.8**	**16.6**	<5.00	**1,760**	<1.00	**7.61**	**5.96**	<1.00	**1.03**	**50.7**	**1,200**
	01/23/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**317**	**1.73**	**21.3**	**3.73**	<1.00	**29**	**64.2**	**8.33**	<5.00	**171**	<1.00	**2.16**	**1.9**	<1.00	<1.00	**35.3**	**398**
	02/04/13	<1.00	<1.00	<1.00	**1.07**	<1.00	**69.6**	**803**	<1.00	**59.8**	**5.52**	<1.00	**58.3**	**6.08**	**1.68**	<5.00	**178**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	02/28/13	<1.00	<1.00	<1.00	**22.3**	**1.48**	<50.0	**210**	<1.00	**26.2**	**3.03**	<1.00	**26.9**	**8.19**	**3.11**	<5.00	**309**	<1.00	**1.73**	**2.6**	<1.00	<1.00	**5.79**	**120**
OS 10E	10/05/12	<1.00	<1.00	<1.00	**8.73**	**2.23**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	**3.33**	**1.21**	<5.00	**213**	<1.00	**1.04**	**1.3**	<1.00	<1.00	<3.00	<100
	01/23/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	**2.57**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	02/04/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	**3.65**	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	02/28/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
OS-15S	10/05/12	<1.00	<1.00	<1.00	**66.9**	**25.4**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	**18.2**	**8.12**	<5.00	**756**	<1.00	**5.22**	**4.83**	<1.00	<1.00	**12.4**	**364**
	01/23/13	<1.00	<1.00	<1.00	**17.3**	**6.5**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.0	<1.0	<5.00	**69.4**	<1.00	<1.00	<1.0	<1.00	<1.00	<3.00	<100
	02/04/13	<1.00	<1.00	<1.00	**11.2**	**4.11**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.0	<1.0	<5.00	**69.8**	<1.00	**1.9**	<1.0	<1.00	<1.00	<3.00	<100
	02/28/13	<1.00	<1.00	<1.00	**3.65**	**1.84**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.0	<1.0	<5.00	**15.1**	<1.00	<1.00	<1.0	<1.00	<1.00	<3.00	<100

Table 10. Results for Volatile Organic Compounds – Overburden Injection Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone (MEK)	Acetone	Benzene	Bromomethane	Carbon Disulfide	Chloroform	Chloromethane	Ethylbenzene	Isopropylbenzene	Methylene chloride	Naphthalene	n-Butylbenzene	n-Propylbenzene	p-Isopropyltoluene	Styrene	Toluene	Xylenes, total	Gasoline Range Organics
	RBSL	--	--	--	--	--	--	--	5	--	--	--	--	700	--	--	25	--	--	--	--	1,000	10,000	--
OS-20S	10/05/12	<1.00	<1.00	<1.00	**105**	**34.5**	<50.0	<50.0	**27.7**	<1.00	<1.00	<1.00	<1.00	**60**	**16.2**	<5.00	**2,430**	<1.00	**9.75**	**7.35**	<1.00	**2.53**	**49.5**	**1,170**
	01/23/13	<1.00	<1.00	<1.00	**1.31**	<1.00	<50.0	**198**	**2.38**	**2.06**	**19**	<1.00	**1.86**	**3.28**	**1.44**	<5.00	**423**	<1.00	**1.05**	<1.00	<1.00	<1.00	<3.00	<100
	02/04/13	<1.00	<1.00	<1.00	**2.3**	<1.00	<50.0	<50.0	**9.12**	**3.19**	**9.81**	<1.00	<1.00	**3.29**	**1.1**	<5.00	**236**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	02/28/13	<1.00	<1.00	<1.00	**26.9**	**4.17**	<50.0	**53.2**	**2.07**	<1.00	**10.2**	<1.00	<1.00	**21.1**	**6.69**	<5.00	**671**	**2.35**	**3.91**	**2.07**	<1.00	<1.00	**12.2**	**193**
OS-25S	10/05/12	<1.00	<1.00	<1.00	**48.9**	**24.8**	<50.0	<50.0	**19.8**	<1.00	<1.00	<1.00	<1.00	**35.6**	**10.1**	<5.00	**754**	<1.00	**6.52**	**2.94**	**1.24**	**1.32**	**28.7**	**796**
	01/23/13	<1.00	<1.00	<1.00	**43.2**	**21.7**	<50.0	<50.0	**17.2**	**2.21**	**9.82**	<1.00	**1.95**	**29.6**	**6.96**	<5.00	**656**	**5.32**	**4.66**	**2.35**	<1.00	**2.03**	**20**	**457**
	02/04/13	<1.00	<1.00	<1.00	**21**	**7.85**	<50.0	**62.9**	**23.9**	**3.36**	**21.4**	<1.00	<1.00	**11.9**	**3.79**	<5.00	**377**	<1.00	**2.76**	**1.3**	<1.00	**2.1**	**8.04**	**221**
	02/28/13	<1.00	<1.00	<1.00	**21.1**	**2.73**	<50.0	<50.0	**27.4**	<1.00	**11.7**	<1.00	<1.00	**26.6**	**7.44**	<5.00	**732**	**2.69**	**4.8**	**1.84**	<1.00	<1.00	**10.1**	**276**

Notes: Units are in micrograms per liter (µg/L).
Detections are in bold. Gray shading represents concentration exceeds Risk Based Screening Level (RBSL)

-- = RBSL not established for this compound
NA - not applicable to well location
< = less than the reported detection limit

Table 11. Results for Semivolatile Organic Compounds – Overburden Injection Performance Monitoring

Monitoring Well	Date Sampled	1-Methyl naphthalene	2-Methyl naphthalene	4-Chloroaniline	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Dibenzo(a,h)anthracene	Dibenzofuran	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Phenol	Pyrene	Diesel Range Organics
	RBSL (µg/L)	25*	25*	--	--	--	--	10	--	10	--	10	--	--	10	10	--	--	--	--	25*	--	--	--	--
MW-13S	03/20/12	**230**	**10.4**	<9.43	**76.4**	**11.5**	**4.72**	<1.89	<1.89	<1.89	<1.89	<1.89	**11.2**	**15.5**	<1.89	<1.89	**12.5**	**2.14**	**32.5**	<1.89	**202**	**21.5**	<9.43	**2.68**	NA
	10/03/12	**458**	**27.1**	<10	**184**	**13.1**	**17.3**	**6.47**	**5.01**	**4.9**	**2.3**	<2	<10	**26**	**4.86**	<2	**21.5**	**18.1**	**44.9**	<2	**32.3**	**75.9**	**10.9**	**21.2**	**131,000**
	02/27/13	**3690**	**1370**	<21.3	**1210**	**228**	**437**	**204**	**173**	**174**	**71.2**	**79.3**	<21.3	**39.7**	**146**	**14.2**	**273**	**541**	**633**	**63**	**3,040**	**2,220**	<21.3	**730**	**121,000**
MW-13D	03/21/12	**136**	**12**	<9.43	**12.2**	**15**	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	<9.43	<9.43	<1.89	<1.89	<9.43	<1.89	**7.51**	<1.89	**56.3**	**2.18**	<9.43	<1.89	NA
	10/03/12	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	<10.2	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	10.2	<2.04	**1,410**
	02/27/13	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<2.22	**111**
MW-13 ISOC	03/21/12	**227**	**26.3**	<9.43	**50.4**	**39.4**	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	<9.43	**11.6**	<1.89	<1.89	**11.7**	<1.89	**23.5**	<1.89	**637**	**7.33**	<9.43	<1.89	NA
	10/03/12	**552**	**12.3**	<11.8	**69.4**	**55**	**4.49**	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	**28.3**	<2.35	<2.35	**17.4**	<2.35	**28.1**	<2.35	**570**	**30.9**	<11.8	<2.35	**4,530**
	01/23/13	**12.4 ***	**6.97 ***	<10.5	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<10.5	<2.11	<2.11	<2.11	**180 ***	<2.11	**16.4 ***	<2.11	**3,490**
	02/04/13	**189**	**91.8**	<12.5	**38.6**	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<12.5	<2.50	**16**	<2.50	**218**	**16.8**	<12.5	<2.50	**2,200**
	02/27/13	**152**	**102**	<10.9	**4.72**	**6.46**	<2.17	<2.17	<2.17	<2.17	<2.17	<2.17	<10.9	<10.9	<2.17	<2.17	<10.9	<2.17	<2.17	<2.17	**1,220**	<2.17	<10.9	<2.17	**5,490**
OS 5S	10/05/12	**605**	**501**	<12.5	**134**	**6.01**	**7.51**	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	**47.4**	<2.5	<2.5	**20.4**	**2.55**	**38.1**	<2.5	**2,090**	**40.6**	<12.5	**3.19**	**6,220**
	01/23/13	**24.9 ***	**18.7 ***	<11.1	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<11.1	<11.1	<2.2	<2.2	<11.1	**4.95 ***	**10.4 ***	<2.2	**49.5 ***	**18.0 ***	<11.1	**5.51 ***	**4,600**
	02/04/13	**48.6**	**39.1**	<12.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	<2.5	**9.4**	<2.5	**108**	**12.4**	<12.5	<2.5	**3,220**
	02/28/13	**83.7**	**76.4**	<10.4	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<10.4	<10.4	<2.08	<2.08	**11.6**	<2.08	**10.5**	<2.08	**195**	**19.4**	<10.4	<2.08	**2,490**
OS 5E	10/05/12	**84.9**	**50.8**	<12.5	**26.6**	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	<2.5	**9.53**	<2.5	**85.1**	**10.3**	<12.5	<2.5	**872**
	01/23/13	**8.54 ***	**2.27 ***	<11.1	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<11.1	<11.1	<2.2	<2.2	<11.1	<2.2	<2.2	<2.2	**11.4 ***	**4.58 ***	<11.1	<2.2	**279**
	02/04/13	**18.9**	**4.14**	<11.8	**2.42**	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	<11.8	<2.35	<2.35	<11.8	<2.35	<2.35	<2.35	**30.5**	**5.9**	<11.8	<2.35	**462**
	02/28/13	**17.8**	**2.75**	<10.5	**2.81**	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<10.5	<10.5	<2.11	<2.11	<10.5	<2.11	<2.11	<2.11	**29.1**	**2.92**	<10.5	<2.11	**460**
OS 10S	10/05/12	**526**	**524**	<12.5	**132**	**4.31**	**8.64**	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	**28.5**	<2.5	<2.5	**19.5**	**2.5**	**41.1**	<2.5	**1,150**	**45.6**	<12.5	**2.99**	**5,460**
	01/23/13	**99.8 ***	**75.7 ***	<11.1	**22.0 ***	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	**13.2 ***	<2.22	**86.6 ***	**16.9 ***	<11.1	<2.22	**3,530**
	02/04/13	**150**	**127**	<11.1	**21.9**	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	**15.7**	<2.22	**169**	**26.7**	<11.1	<2.22	**3,070**
	02/28/13	**190**	**177**	<10.5	**44.5**	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<10.5	<10.5	<2.11	<2.11	<10.5	<2.11	**17.4**	<2.11	**231**	**28.7**	<10.5	<2.11	**2,460**
OS 10E	10/05/12	**142**	**67.2**	**37.8**	**56.9**	<2.5	**6.9**	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	**2.66**	**24**	<2.5	**111**	**35.3**	<12.5	**3.45**	**1,310**
	01/23/13	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<2.22	**124**
	02/04/13	<2.35	<2.35	<11.8	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	<11.8	<2.35	<2.35	<11.8	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	<2.35	**197**
	02/28/13	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	<10.2	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	**2.57**	<2.04	<10.2	<2.04	**152**

Table 11. Results for Semivolatile Organic Compounds – Overburden Injection Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1-Methyl naphthalene	2-Methyl naphthalene	4-Chloroaniline	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Dibenzo(a,h)anthracene	Dibenzofuran	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Phenol	Pyrene	Diesel Range Organics
	RBSL (µg/L)	25*	25*	--	--	--	--	10	--	10	--	10	--	--	10	10	--	--	--	--	25*	--	--	--	--
OS 15S	10/05/12	**424**	**226**	<10.2	**141**	**4.69**	**9.16**	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	**11.5**	<2.04	<2.04	**15.2**	**4.25**	**39**	<2.04	**349**	**45.6**	<10.2	**4.98**	**3,940**
	01/23/13	**17.5 ***	<2.22	<11.1	**13.1 ***	<2.22	**2.62 ***	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	**2.34 ***	**4.24 ***	<2.22	<2.22	**2.87 ***	<11.1	**3.11 ***	**839**
	02/04/13	<2.50	<2.50	<12.5	**6.29**	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	**3.33**	**933**
	02/28/13	**5.23**	<2.04	<10.2	**10.7**	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	**113**	<10.2	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	**2.65**	**566**
OS 20S	10/05/12	**744**	**607**	<11.8	**187**	**8.01**	**8.86**	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	**53.8**	<2.35	<2.35	**29**	**2.53**	**51.8**	<2.35	**1,660**	**50.4**	<11.8	**3.55**	**6,290**
	01/23/13	**202 H**	**96.3 H**	<11.8	**30.2 H**	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	<11.8	<2.35	<2.35	**11.9 H**	<2.35	**17.7 H**	<2.35	**218 H**	**20.9 H**	<11.8	<2.35	**2,940**
	02/04/13	**189**	**91.8**	<12.5	**38.6**	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<12.5	<12.5	<2.50	<2.50	<12.5	<2.50	**16**	<2.50	**218**	**16.8**	<12.5	<2.50	**2,200**
	02/28/13	**340**	**200**	<10.3	**59.1**	<2.06	**2.73**	<2.06	<2.06	<2.06	<2.06	<2.06	<10.3	<10.3	<2.06	<2.06	**14**	**2.27**	**21.1**	<2.06	**653**	**27.8**	<10.3	**3.46**	**3,820**
OS 25S	10/05/12	**573**	**78.1**	<13.3	**164**	**14.1**	**9.3**	<2.67	<2.67	<2.67	<2.67	<2.67	<13.3	**38.5**	<2.67	<2.67	**35.6**	<2.67	**53**	<2.67	**544**	**54.7**	<13.3	**3.31**	**4,720**
	01/23/13	**378 ***	**61.3 ***	<10.8	**74.4 ***	**12.4 ***	**5.73 ***	<2.16	<2.16	<2.16	<2.16	<2.16	<10.8	**19.5 ***	<2.16	<2.16	**24.6 ***	<2.16	**36.5 ***	<2.16	**393 ***	**37.0 ***	<10.8	**2.45 ***	**2,940**
	02/04/13	**448**	**62.1**	<11.8	**95.7**	**13.5**	**7.12**	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	**20**	<2.35	<2.35	**33.3**	<2.35	**46.7**	<2.35	**371**	**47.2**	<11.8	**2.74**	**4,680**
	02/28/13	**424**	**59.3**	<10.0	**91.1**	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<10.0	**15.4**	<2.00	<2.00	**29.6**	<2.00	**39.3**	<2.00	**409**	**39.7**	<10.0	**2.02**	**276**

* LCS or LCSD exceeds the control limits.

Notes: Units are in micrograms per liter (µg/L).
Detections are in bold. Shaded values exceed RBSLs. RBSL for methyl naphthalenes is 25 µg/L for combined isomers.

--- = RBSL not established for this compound
H = sample was prepped or analyzed beyond the specified holding time
NA = not analyzed

Table 12. Results for Inorganic Compounds – Overburden Injection Performance Monitoring

Monitoring Well ID	Date Sampled	Arsenic	Chromium	Lead	Selenium	Nitrate-Nitrogen	Sulfate	Alkalinity, Total ($CaCO_3$)
	RBSL (mg/L)	*0.05*	*0.1*	*0.015*	*0.05*	--	--	--
MW-13S	10/03/12	<0.01	<0.005	<0.005	<0.01	**2**	**58.4**	**187**
	02/27/13	<0.05	**0.225**	<0.025	<0.05	NA	**7,380**	NA
MW-13D	10/03/12	<0.01	<0.005	<0.005	<0.01	**0.532**	**7.07**	**129**
	02/27/13	**0.0110**	<0.005	<0.005	<0.01	NA	**4.74**	NA
MW-13 ISOC	10/03/12	<0.01	<0.005	<0.005	<0.01	<0.1	**80.8**	**233**
	01/23/13	<0.01	**0.031**	**0.0075**	**0.0311**	NA	**7,020**	NA
	02/04/13	<0.01	**0.044**	<0.005	<0.01	NA	**2,020**	NA
	02/27/13	<0.05	<0.025	<0.025	<0.05	NA	**5,630**	NA
OS-5N	10/05/12	<0.01	<0.005	**0.005**	<0.01	NA	**48.6**	NA
	02/28/13	<0.01	**0.0605**	<0.005	<0.01	NA	**1,160**	NA
OS-5S	10/05/12	<0.01	<0.005	**0.005**	<0.01	NA	**44.8**	NA
	01/23/13	**0.0416**	**0.769**	**0.0331**	**0.0558**	NA	**27,700**	NA
	02/04/13	**0.0390**	**3.520**	<0.005	**0.182**	NA	**36,200**	NA
	02/28/13	<0.01	**2.040**	<0.005	<0.01	NA	**17,800**	NA
OS-5E	10/05/12	<0.01	<0.005	<0.005	<0.01	NA	**26.1**	NA
	01/23/13	<0.01	**0.722**	**0.067**	**0.0317**	NA	**5,180**	NA
	02/04/13	**0.0123**	**0.433**	**0.0148**	**0.0161**	NA	**2,370**	NA
	02/28/13	<0.01	**0.097**	**0.0233**	<0.01	NA	**948**	NA
OS-10S	10/05/12	<0.01	<0.005	<0.005	<0.01	NA	**43.7**	NA
	01/23/13	**0.0421**	**0.0148**	**0.0208**	**0.0192**	NA	**6,470**	NA
	02/04/13	<0.01	<0.005	<0.005	<0.01	NA	**11,800**	NA
	02/28/13	**0.0360**	**0.00830**	**0.0293**	**0.0178**	NA	**8,670**	NA

Table 12. Results for Inorganic Compounds – Overburden Injection Performance Monitoring (Continued)

Monitoring Well ID	Date Sampled	Arsenic	Chromium	Lead	Selenium	Nitrate-Nitrogen	Sulfate	Alkalinity, Total ($CaCO_3$)
	RBSL (mg/L)	*0.05*	*0.1*	*0.015*	*0.05*	--	--	--
OS 10E	10/05/12	<0.01	<0.005	<0.005	<0.01	NA	**20.3**	NA
	01/23/13	<0.01	**0.00760**	**0.0115**	<0.01	NA	**134**	NA
	02/04/13	<0.01	**0.02450**	**0.0208**	<0.01	NA	**82**	NA
	02/28/13	<0.01	<0.005	**0.0055**	<0.01	NA	**94.2**	NA
OS 15S	10/04/12	NA	NA	NA	NA	NA	**44.1**	NA
	01/23/13	<0.01	<0.005	<0.005	<0.01	NA	**41.6**	NA
	02/04/13	<0.01	<0.005	<0.005	<0.01	NA	**45.6**	NA
	02/28/13	<0.01	<0.005	<0.005	<0.01	NA	**35.2**	NA
OS 20S	10/05/12	<0.01	<0.005	<0.005	<0.01	NA	**9.62**	NA
	01/23/13	**0.0120**	**0.0927**	**0.0224**	<0.01	NA	**5,220**	NA
	02/04/13	<0.01	**0.0443**	<0.005	<0.01	NA	**2,020**	NA
	02/28/13	**0.0107**	**0.0152**	<0.005	<0.01	NA	**979**	NA
OS 25S	10/05/12	<0.01	<0.005	<0.005	<0.01	NA	**14.4**	NA
	01/23/13	<0.01	**0.0606**	**0.0211**	<0.01	NA	**2,170**	NA
	02/04/13	<0.01	**0.0374**	**0.0066**	<0.01	NA	**1,820**	NA
	02/28/13	<0.01	**0.0190**	<0.005	<0.01	NA	**639**	NA

Notes: Units are in milligrams per liter (mg/L).
Detections are in bold. Shaded values exceed RBSLs.

--- = RBSL not established for this compound
$CaCO_3$ = calcium carbonate
ISCO = in-situ chemical oxidation
mg/L = milligrams per liter
NA = not analyzed
RBSL = Risk Based Screening Level

DO concentrations measured in the baseline event ranged from 0.02 to 2.18 mg/L with an average of 0.56 mg/L. ORP values measured in the baseline event ranged from -74 to 93 mV with an average of -16 mV. The baseline DO and ORP measurements indicate an anaerobic environment with a of pH average of 6.11 SU.

The results of the sampling indicated BTEX and light hydrocarbon concentrations similar to historic results at MW-13S. However, PAH and TPH-DRO concentrations in groundwater from these wells were several times greater than previously estimated from historic data. Concentrations of sulfate ranged from 9.62 to 58.4 mg/L.

7.3.2 Evaluation of Oxidant Delivery

Oxidant delivery effectiveness was evaluated by the collection of samples for persulfate concentrations using Klozur® or Hach persulfate kits and field geochemistry parameters. Due to a disruption in the ability to acquire the field test kits from FMC Corporation, two field events did not result in collection of persulfate concentration data. The following discussion is based on three events conducted during the first, third, and fifth week after completion of injection. During these events, the injection distribution pattern, oxidant persistence, and area of influence are readily apparent. Geochemical and persulfate test kit results are summarized in Table 9.

On January 18, 2013, water quality parameters and field screening analyses were recorded to evaluate the persistence and the transport of the injected solution in the subsurface. Several consistent geochemical changes were noted in the observation wells that were impacted by injection of base-activated sodium persulfate including detection of residual persulfate, an increase in ORP, an increase in sulfate, and an increase in specific conductance. The observation wells nearest the injection well, OS 5N, OS 5S, and OS 5E, had measured persulfate concentrations of 44 mg/L in each of the wells indicating uniform distribution and a radial area of influence. Observation wells OS 5N, OS 5S, and OS 5E also exhibited an increase in pH from a pre-injection average of 6.14 to 10.54 SU, indicating that during injection and for at least 8 days after injection, persulfate activation resulting in free radical generation was occurring. DO increased from an average of 0.69 to 11.82 mg/L and ORP increased from an average of 2 to 173 mV, indicating the injection was driving the shallow overburden aquifer towards a strongly oxidizing environment. No other monitoring locations exist north of OS 5N and, therefore, there is no way to tell how far the area of influence extended in the upgradient direction.

Within a 10-foot radius of the injection well, the changes in geochemical indicators were also significant. Both the side-gradient well (OS 10E) and the downgradient well (OS 10S) exhibited elevated persulfate concentrations. No other monitoring locations exist east of OS 10E; therefore there is no way to tell how far the area of influence extended in the side-gradient direction. Observation wells OS 10 and OS 10E saw pH increase from a pre-injection average of 6.09 to 7.90 SU, DO increased from an average of 0.27 to 3.74 mg/L, and ORP increased from an average of -50 to 250 mV indicating a strong oxidizing environment.

The wells farther downgradient (OS 15S, OS 20S, and OS 25S) all had measurable concentrations of persulfate (2.5 grams per liter [g/L]) indicating that the oxidant travelled approximately 25 feet in 8 days. The low persulfate concentrations eight days after completion of the injections suggested that the observed levels were more likely a first occurrence and not the full wave of the oxidant mass. Significant changes in DO were observed at well OS 15S and OS 20S where DO levels increased from less than 0.3 mg/L to greater than 5 mg/L. Additionally, ORP in the three downgradient wells increased from a baseline of -10 to 190.6 mV. The second sampling event on January 28, 2013 provided evidence of continued advective transport of the persulfate in the downgradient direction. OS 5N, the upgradient observation well, saw an 80% decline in the persulfate concentration and DO declined by 35%. However, ORP readings indicated maintenance of an oxidative environment. Within a 10-foot radius of the injection well, the persulfate concentrations no longer exhibited a uniform distribution of the oxidant, but show preferential distribution in the downgradient direction. Persulfate concentrations slightly increased at downgradient well OS 5S, but increased by a factor of four at OS 10S (5.5 to 29.55 g/L). Along the side-gradient wells, OS 5E and OS 10E had decreases in persulfate concentrations of approximately 70%. Some of this decline in the side-gradient direction is a response from the formation to try to equalize after the injection artificially created a stronger than normal gradient in this direction.

The geochemical data from the field measurements three weeks after completion of the injections indicated that oxidative conditions were being maintained within 10 feet of the injection point. ORP for the observation points located 5 feet from the injection point averaged 222 mV. The mean ORP at 10 feet from the injection point (245 mV) remained consistent with the level observed one week after injection.

The wells farther downgradient (OS 15S, OS 20S, and OS 25S) all had measurable concentrations of persulfate. As of the third week of post injection monitoring, the concentration of persulfate at well OS 15S was ~120% greater than in the first week of post injection monitoring. Persulfate concentrations at wells OS 20S and OS 25S were similar to those observed during the week 1 sampling event.

DO concentrations at wells OS 20S and OS 25S in the third week of post injection monitoring had increased approximately 2 mg/L above the levels observed during the first week of post injection monitoring. The mean ORP in wells OS 15S and OS 20S in the third week of post injection monitoring was 270 mV compared to 115 mV in the first week of monitoring. At well OS 25S, DO increased from 0.43 to 2.69 mg/L, but ORP dropped 284 mV. These data indicated that oxidative conditions were still being established three weeks after injection to a distance of 20 feet from the injection point. At three weeks after injection, the data from OS 25S suggested that the initial oxidative conditions observed in the first week of monitoring were waning and that OS 25S was a terminal point with respect to the area of influence.

The third sampling event conducted five weeks after injection (February 12, 2013), continued to show advection within the shallow overburden aquifer. The oxidant concentrations continued to remain elevated at the observation wells nearest the injection well, with a rebound in the side-gradient direction and a continued preference for the downgradient direction.

The oxidant mass remained very elevated at wells OS 5E and OS 5S (>20 g/L) with oxidant mass increasing at OS 5E relative to the level in the third week of post injection monitoring. Within 5 feet of the injection point, ORP averaged 244 mV. Although oxidant mass also remained at 20 g/L at wells 10 feet from the injection point, ORP had declined from the levels observed in the third week following injection.

Peak persulfate concentrations were observed at well OS 10E (20 g/L) five weeks after injection. Persulfate concentrations remained elevated at OS 10S during this monitoring event. At a distance of 10 feet from the injection point, the mean ORP (105 mV) was approximately half of the level observed at the previous monitoring event, but remained oxidative. There was not an observation well along the side-gradient axis beyond OS 10E, but the data infer influence beyond 10 feet in that direction.

Peak persulfate concentrations were also observed at downgradient wells OS 15S and OS 20S indicating advective transport of the reagent to this distance five weeks after injection. Subsequent monitoring events (February 18 and February 28) at these wells observed increasing DO and ORP levels confirming the advective transport time indicated by the persulfate concentrations.

The wells farther downgradient (OS 20S and OS 25S) all had measurable concentrations of persulfate. The concentration of persulfate at OS 20S was ~50% greater than observed in the third week, but levels at OS 25S remained constant with the concentration observed during the week 1 sampling event. This data indicated that oxidant delivery during injection extended approximately 25 feet downgradient, but that subsequent advective transport had not resulted in the trailing edge of reagent reaching this distance in five weeks.

Preliminary estimates of travel time presented in the Work Plan indicated that the oxidant would reach a downgradient distance of 30 feet in about 9 to 14 days. Based on the measured concentrations of persulfate, it appears that oxidant travels at a velocity of approximately 3 feet per day in the overburden, reaching a downgradient distance of 25 feet in at least 8 days with the trailing edge of the oxidant passing through 20 feet downgradient in approximately 30-35 days. It does not appear that any significant concentration of oxidant moved beyond 25 feet from the injection point. Shortly after injection, groundwater pH increased to alkaline conditions within a 10-foot radius of the injection. Groundwater pH at this distance fluctuated for up to five weeks after injection. The near neutral pH at distances beyond 10 feet suggests that the residual acidity in the soil or soil buffering demand was greater than measured in the laboratory. The potential for additional alkali was noted in the Work Plan and is likely the result of hydroxide consumption in saponification reactions that emulsify the coal tar contaminants causing desorption from soil and residual DNAPL ganglia. It appears that oxidant distribution can be described by an ellipse with a primary axis in the downgradient direction of between 20 and 25 feet and a secondary axis of approximately 12-15 feet. Influence from injection extends at least five feet in the upgradient direction. Persulfate was observed to persist in the subsurface for a period of at least 5 weeks.

7.3.3 Evaluation of Contaminant Treatment

Effectiveness of the amendment at treating the MGP contaminants was evaluated by the collection of the groundwater samples for laboratory analysis during three events (January 23, February 4, and February 28, 2013) following the injection. Prior to the injection, benzene and naphthalene were the two primary COCs detected in groundwater at concentrations above the RBSLs within the pilot area. Benzene and naphthalene concentrations by EPA Method 8260 exceeded their respective RBSLs at MW-13S, MW-13 ISOC, OS 5S, OS 20S, and OS 25S. Only naphthalene concentrations exceeded the RBSL at the remaining overburden observation wells. Table 10 summarizes the VOC and TPH-GRO results from the three post injection monitoring events. Results for PAHs and TPH-DRO are summarized in Table 11.

2-Week Post-Injection – January 23, 2013

The two-week post-injection results indicated that substantial mineralization had been achieved from the injection. Benzene concentrations were all below the respective RBSLs with the exception of OS 25S (Table 10). Within 15 feet of the injection point, BTEX was below detection limits or where detected BTEX concentrations had declined by greater than 90%. Alkyl benzene (i.e., trimethylbenzene, butylbenzene) concentrations had declined by greater than 90% within 10 feet of the injection point and had declined by 75% at 15 feet from the injection well. Except at well OS 10S, TPH-GRO concentrations within 15 feet of the injection point had declined by 85% or more.

BTEX, alkyl benzene, and TPH-GRO concentrations at well OS 20S had declined by more than 90% from their respective baseline levels. Concentrations of these species had declined only 10 to 40% at well OS 25S. As described in the preceding section, data from the pilot indicated that well OS 25S was at the downgradient limit of effects from the injection.

Naphthalene concentrations by EPA Method 8260 were decreased by more than 80% up to 20 feet downgradient, and within 15 feet of the injection point concentrations were reduced by more than 90%. Concentrations of methyl naphthalenes and routinely detected PAHs were also reduced by greater than 80% within 15 feet of the injection point. At OS 20S and OS 25S, the levels of these contaminants had declined 79% and approximately 40%, respectively (Table 11). Except at well OS 10S, TPH-DRO levels had declined from 55% to 90% at the wells within 20 feet of the injection point. At well OS 10S and OS 25S, concentrations of TPH-DRO had been reduced by approximately 40%.

Table 12 presents concentrations of arsenic, chromium, lead, selenium, and sulfate from groundwater samples. As expected, sulfate concentrations increased significantly after the injection since it is a byproduct of the persulfate reaction.

Concentrations of metals that are more mobile under oxidizing conditions or high pH (chromium, lead, and selenium) increased as a result of the injection activities. The increase in metals concentrations was generally limited to within a 10-foot radius of the injection well. Subsequent monitoring events indicated that mobilization of these metals was transient in nature.

4-Week Post-Injection – February 4, 2013

Approximately four weeks post-injection, benzene concentrations were all less than the 0.1 μg/L method detection limit (MDL) with the exception of wells OS 20S and OS 25S (Table 10). These two wells exhibited a slight rebound likely caused by their distance from the injection well.

Alkyl benzene concentrations remained at non-detect or at less than 10% of their baseline within 10 feet of the injection point. Alkyl benzene concentrations had declined by 85% from their baseline at 15 feet from the injection well indicating continued mineralization of these species. Additional mineralization of the alkyl benzenes occurred at OS 25S where their concentration had been reduced by 60% from their baseline. TPH-GRO concentrations within 15 feet of the injection point had declined by 85% or more. Additional mineralization of TPH-GRO occurred at OS 10S where concentrations had dropped from 398 μg/L to non-detect between the first sampling event and this event.

Concentrations of BTEX, alkyl benzene, and TPH-GRO had further declined at well OS 25S. Alkyl benzene and TPH-GRO levels at OS 25S had declined by 61% and

72% from their respective baselines indicating that the injected oxidant was affecting contaminants at the limit of the area of influence.

Naphthalene concentrations by EPA Method 8260 were decreased by at least 90% as compared to baseline up to 20 feet downgradient, and the concentration 25 feet downgradient was reduced 50% compared to baseline. Except at well OS 10S, concentrations of methyl naphthalenes and routinely detected PAHs were reduced by greater than 95% within 15 feet of the injection point. At OS 10S and OS 20S, the levels of these contaminants had declined by greater than 75% relative to baseline. Some slight rebound in the concentrations of these contaminants occurred at OS 25S (Table 11). Some rebound also occurred with TPH-DRO levels within 20 feet of the injection point, but levels remained at approximately 50% of their baseline.

7-Week Post-Injection – February 28, 2013

Approximately seven weeks post-injection, benzene concentrations were all less than the MDL with the exception of wells OS 20S and OS 25S (Table 10). Additional mineralization of benzene had occurred at OS 20S since the February 4 sampling event. BTEX concentrations remained at less than 10% of their baseline within 15 feet of the injection point. Some rebound in BTEX occurred at OS 20S and OS 25S.

Except at well OS 10S, alkyl benzene concentrations were non-detect or at less than 10% of their baseline within 15 feet of the injection point. Alkyl benzene concentrations at OS 10S and OS 20S exhibited some slight rebound, but remained at less than 30% of their baseline at 15 feet from the injection well indicating continued mineralization of these species.

TPH-GRO concentrations within 20 feet of the injection point had declined by 85% or more. At OS 25S some rebound in concentrations occurred, but the TPH-GRO level remained less than 35% of its baseline.

Naphthalene concentrations by EPA Method 8260 were decreased by at least 80% compared to baseline up to 15 feet downgradient. Some rebound in naphthalene concentrations occurred at OS 20S and OS 25S, and the concentration 25 feet downgradient was reduced 50% compared to baseline. Except at well OS 10S, concentrations of methyl naphthalenes and routinely detected PAHs were reduced by greater than 85% within 15 feet of the injection point. At OS 10S and OS 20S, the levels of these contaminants had declined by greater than 65% relative to baseline. The data at seven weeks indicated some slight rebound in the concentrations of PAHs at 20 and 25 feet from the injection point (Table 11). Some rebound in contaminant concentrations is common with ISCO. In general, the data at seven weeks after injection indicated some continued mineralization of TPH-DRO except at 20 feet from the injection point.

Concentrations of chromium had declined from levels observed at two weeks after injection. Except at OS 5S where vanadium concentrations increased, the levels of both lead and vanadium were generally lower than at two weeks after injection indicating that mobilization of these species was transient in nature.

8.0 PILOT ISCO INJECTION FOR THE PWR ZONE

8.1 PWR Zone ISCO Injection Zone Process and Conditions

8.1.1 PWR Injection Loading

Successful injection in the PWR requires introduction of the reagents into interconnected water bearing fractures and channels. Although the initial pilot studies described in Section 6.1 were intended to identify fracture patterns and interconnected water bearing zones, there was still some uncertainty concerning the probability of successful injection in this zone. Interconnected fractures or channels determined from aquifer testing may have decreasing apertures along the injection path or may have become partially soil filled at some point within the injection zone retarding reagent distribution. Conversely, fracture apertures may increase along the downgradient flow path of the injection zone providing rapid distribution with inadequate contact time.

Injection in the PWR will be limited by the available void volume in this lithologic regime. Geotechnical studies of the Piedmont have indicated that this zone will have a void volume of only 15% to 25%. Accordingly, the volume available to receive injectate within 12 to 15 radial feet of an injection well is limited to 5,000 to 9,000 gallons.

The *Chemical Oxidation Pilot Test Work Plan* initially estimated oxidant dosing for the PWR based on an elliptical area extending 5 feet upgradient, 15 feet downgradient, and 7 feet side gradient from the injection well. Step testing indicated influence to at least 10 feet along both axes, and therefore, the area of influence and oxidant loading were increased from the initial estimate in the Work Plan. Data from the October sampling also indicated greater contaminant mass than originally estimated. Based on these considerations, the loading for the PWR ISCO injection was increased to involve a total of approximately 3,800 lbs of sodium persulfate injected as a 20% solution (approximately 2,000 gallons). The revised activator demand was estimated at approximately 500 gallons of 25% sodium hydroxide or 650 gallons of 20% sodium hydroxide solution.

Due to the limited porosity of the PWR, the total volume of the reagents was planned to be injected in four separate events that were implemented approximately one week apart. Each separate event involved injection of one fourth of the total reagent volume. Based on the results from the step tests, the reagents will be injected at a rate of approximately 0.5 to 1 gpm and 5 to 10 psi. Post injection monitoring is described in Section 8.2.

8.1.2 PWR Zone Injection Process

The PWR zone ISCO injection process was the same as the shallow zone injection process described in Section 7.1.2 of this report, with the exception of having a decreased flow rate. The two solutions were injected simultaneously at flow rate between 0.5 to 1 gpm at a ratio of 4 to 1 sodium persulfate solution to sodium hydroxide. The fluid delivery pressure varied from 5 to 10 psi dependent on the flow rate.

8.1.3 PWR Hydroxide Activated Injection Zone Conditions

Groundwater parameters were measured in the PWR observation wells periodically during injection to monitor the effectiveness and distribution of the injected reagents. Geochemical parameters were also monitored in the shallow observation wells periodically to determine if they were influenced by the PWR ISCO injection. Table 13 provides a summary of the injection activities and observations from that monitoring during injection.

Geochemical parameters monitored during injection are included in Appendix G. Table 13 provides a summary of the daily volumes of injected sodium persulfate solution and sodium hydroxide and comments on the injection process.

Week 1 Injection – March 5, 2013

During the first week of injection activities, AMEC took delivery of the chemicals needed for the PWR zone injection and securely stored them behind a locked chain linked fence.

In the first week of injections into the PWR zone, 389 gallons of persulfate solution and 103 gallons of sodium hydroxide were injected simultaneously at ratio of 4 to 1, respectively. Initial geochemical parameters in the PWR observation wells indicated limited specific conductivities (0.7 to 8.9 µS/cm), highly positive ORP values (120 to 320 mV), neutral to slightly acidic pH (6.0 to 7.0 SU), and low DO values (<1.0 mg/L). These results were consistent with measurements from the week of February 28, 2013 (Table 9). The very positive ORP values in the PWR wells indicated the oxidation effects from the overburden injections conducted in December 2012 and January 2013.

Similar baseline geochemical parameters were observed in the shallow observation wells. Specific conductance values were 0.1 to 4.5 µS/cm and pH was slightly acidic with pH values of approximately 6.0 to 7.0 SU. The shallow observation wells generally exhibited a positive ORP value ranging from -73 mV at OS 25S to 286 mV at OS 10S with a mean of approximately 130 mV. DO values were generally less than 1.0 mg/L.

Table 13. Summary of PWR Hydroxide Activated Injection Activities

Date	Sodium Persulfate Solution Injected (gal)	NaOH Injected (gal)	Comments
Week 1			
3/5/2013	171	43.30	Simultaneously injected 4:1 persulfate to NaOH ratio.
3/6/2013	218	59.20	Simultaneously injected 4:1 persulfate to NaOH ratio.
Total	**389**	**102.50**	
Week 2			
3/11/2013	47	46.20	Simultaneously injected 4:1 persulfate to NaOH ratio. Lead combined injection with 34 gal of NaOH
3/12/2013	225	96.30	Simultaneously injected 4:1 persulfate to NaOH ratio. Lead combined injection with 40 gal of NaOH. Increased flow rate from 0.5 to 0.75 gpm and checked mounding. Returned to 0.5 gpm.
3/13/2013	120	90.90	Simultaneously injected 4:1 persulfate to NaOH ratio. Lead combined injection with 16 gal of NaOH. Stopped persulfate injection at 11:15 (52 gal) and continued NaOH. Stopped NaOH at 12:50; waited an hour to take parameters. Restart both chemicals at 14:20. Stopped persulfate at 18:00 and follow with 17.5 gal of NaOH.
3/14/2013	123	30.00	Simultaneously injected 4:1 persulfate to NaOH ratio. Stopped NaOH at 11:10 (30 gal) and continue persulfate (73 gal).
Total	**515**	**263.40**	
Week 3			
3/19/2013	201	66.00	Simultaneously injected 4:1 persulfate to NaOH ratio. Lead combined injection with 10 gal of NaOH. 16:30 turn off NaOH and continued persulfate injection. 17:30 stop injection.
3/20/2013	32	25.60	Simultaneously injected 2:1 persulfate to NaOH ratio.
3/21/2013	107	20.00	Simultaneously injected 4:1 persulfate to NaOH ratio. Turned NaOH (20 gal) off at 09:00 and continued persulfate (10 gal).
Total	**340**	**111.60**	
Grand Total	**1,244**	**477.50**	

Notes: gal = gallons
gpm = gallons per minute
NaOH = sodium hydroxide
PWR = partially weathered rock

Significant changes in pH, DO, temperature, and conductivity were not observed in the PWR observation wells measurements during the first week of injection. Limited changes in these parameters had occurred during the first week and part of the second week during the shallow zone injection due to the need to overcome residual soil acidity. Therefore, the absence of notable changes in pH and conductivity in the first week of injection in the PWR was expected.

ORP went from very positive values to negative (-30 to -70 mV) during the second day of injection. By the end of the first week of injection, ORP values at most PWR wells were near -150 mV. Geochemical monitoring of well MW-13S was terminated when a black viscous substance was discovered in the bottom 5 feet of the well. The substance was believed to be MGP DNAPL that was desorbed from the PWR matrix during the shallow zone ISCO injections. As described in Section 8.1.5, a multi phase extraction event (MPE) was subsequently implemented to address this situation.

Mounding of 1.5 to 2 feet was observed at the observation wells closest to the injection well. Mounding was inversely related to distance from the injection point ranging from 0.5 to 1 feet at distances of 10 feet and 5 feet from the injection well. The observed mounding indicated hydraulic connection along the lines of observation points.

Week 2 Injection – March 11, 2013

Due to the unexpected ORP values observed during the first week of injection, a new in-well probe was obtained for the second week of injection. Before starting the second week of injection, geochemical parameters were measured in all PWR observation wells. The groundwater parameters were consistent with the results from the first week of injection, with exception of ORP values. ORP values, which had been very negative at the conclusion of the first week of injection (indicating reductive conditions), had reverted back to being highly positive. For the second week of injection, it was decided to lead the persulfate with about 20 to 40 gallons of sodium hydroxide since this approach had been successful with overcoming residual acidity in the shallow zone. Additionally on March 12, the injection flow rate was increased from 0.5 to 0.75 gpm in an attempt to distribute the reagents more effectively. After 5 hours of injection at the increased flow rate, geochemical parameters indicated no significant difference from previous measurements and the flow rate was decreased back to 0.5 gpm.

Groundwater parameters taken at the end of the day on March 12 indicated that ORP values had become very negative at most PWR wells ranging from -29 to -335 mV. The only PWR observation wells with positive ORP at the end of the second day of injection were OR 3W and OR 10W, and both of those wells had exhibited negative ORP readings earlier in the day. Additionally, pH values had not increased in the PWR observation wells with the exception of OR 3S and MW-13 ISOC that had a pH of 11.86 and 12.0 SU, respectively. The high pH observed in MW-13 ISOC suggests that it is well connected to a large aperture fracture that intersects the PWR injection well screen. Elevated but fluctuating DO values were observed at most PWR wells except OS 5S with the highest DO level being observed at OR 3S (10.85 mg/L).

Conversely, the shallow wells nearest the PWR injection point exhibited negative ORP values at the beginning of the second week of activities. Shallow observation wells farther removed from the PWR injection point (OS 15S and OS 20S) exhibited positive ORP readings at the beginning of the second week. By the second day of injection, the shallow observation wells nearest to the PWR injection point were exhibiting positive ORP values.

On March 13, elevated pH levels were observed in downgradient shallow observation wells OS 15S and OS 20S. Elevated pH was not observed at any PWR observation well except OR 3S. The elevated pH at these two overburden observation wells also corresponded with an inversion of the ORP readings at these wells from positive readings to very negative levels (-300 mV). In order to observe each chemical's effect on geochemistry in the PWR observation wells, sodium hydroxide and sodium persulfate were injected individually and in combination. Initially, sixteen gallons of sodium hydroxide was injected prior to injection of both solutions. After 2 hours of injection of both chemicals, the sodium persulfate solution feed was turned off and sodium hydroxide injection continued. After 1.5 hours, the sodium hydroxide feed was turned off and the aquifer was allowed to rest for an hour before geochemical parameters were measured. No significant changes in geochemistry were observed in the PWR aquifer.

On March 14, 30 gallons of sodium hydroxide and 73 gallons of sodium persulfate solution were simultaneously injected, then followed by 50 gallons of sodium persulfate solution individually. A total of 515 gallons of sodium persulfate and 264 gallons of sodium hydroxide were injected during the second week of PWR injection activities.

Groundwater parameters taken at the end of the day on March 14, indicated pH conditions had not increased in the PWR observation wells. The ORP was negative in all of the PWR observation wells ranging from -40 to -370 mV. The ORP remained positive in the shallow observation wells. Throughout the second week, the groundwater measurement probe was recalibrated several times and read properly upon each recalibration.

Week 3 Injection – March 18, 2013

Initial geochemistry results during the third week of injection indicated minimal changes in the PWR observation wells relative to the final readings of the previous week. However, ORP values decreased from approximately 200 mV to a range of

-140 to -370 mV in every shallow observation well, indicating a very reductive environment in the overburden.

Prior to injection of both solutions, approximately 10 gallons of sodium hydroxide was injected first. Approximately 56 gallons of sodium hydroxide and 170 gallons of sodium persulfate solution were simultaneously injected, followed by 30 gallons of sodium persulfate solution individually. The top 5 feet and bottom 5 feet of every shallow observation well and PWR observation well was bailed out with a clear bailer to see if any contamination had desorbed during the PWR injection. No visual evidence of desorbed coal tar was found in any of the observation wells, with the exception of the previously known DNAPL in MW-13S. This material was subsequently removed as described in Section 8.1.5.

On March 19, readings in the shallow observation wells indicated a pH of approximately 10 SU at well OS 5S, but relatively neutral pH at the remaining shallow observation wells. In the PWR wells, the pH was ~12.5 SU at OR 3S and 9.7 SU at MW-13 ISOC. The remaining PWR wells had slightly acidic pH. The ORP in both the overburden and PWR observation wells ranged from -100 to -400 mV, indicating a reducing environment when an oxidizing environment is expected. Repeated recalibration and measurements yielded the same results. Similar results were obtained at the end of the day of injection and on the following morning.

On March 20, the ratio of sodium persulfate solution to alkaline activator was doubled to 2 to 1 for a short period of time to evaluate whether a reduced loading of sodium hydroxide would allow the geochemistry to adjust toward a less reduced environment. A total of 32 gallons of sodium persulfate solutions and 26 gallons of activator were injected for the day. No significant changes in the ORP values in the PWR observation wells resulted from the adjusted chemistry.

On March 21, 20 gallons of sodium hydroxide and 10 gallons of sodium persulfate solution were simultaneously injected. This injection was followed by injection of 97 gallons of only sodium persulfate solution to determine if geochemical conditions would become more oxidizing in nature.

Groundwater parameters in the PWR observation wells on March 21 were consistent with previous measurements. ORP values continued to be very reductive and pH values had not increased in the PWR observation wells. Observation wells OR 3S and MW-13 ISOC continued to display an elevated pH of 13.7 and 9.9 SU, respectively. Shallow observations wells continued to have very reductive ORP values, ranging from -258 to -397 mV.

The fourth week of injection operations was suspended in order to evaluate the potential causes for the observed reductive environment.

8.1.4 PWR Zone Activator Change Rational

Several factors were postulated as working in conjunction to cause the reductive environment in the monitoring results. First, injection in the shallow overburden zone affected the PWR and caused desorption and mobilization of MGP wastes that was trapped in certain PWR fractures. This hypothesis was supported by both analytical data and visual observations. Concentrations of VOCs measured in wells OR 3S, OR 3W, OR 5S, and OR 10W in February 2013 were significantly lower than in October 2012 (Table 10). Similarly, concentrations of PAHs and DRO were significantly lower in wells OR 3S, OR 5S, and OR 10W in February 2013 than in October 2012. Mobilization of the MGP DNAPL as a result of the overburden injections was supported by visual evidence. On March 19, bailer samples were collected from the bottom 5 feet and top 5 feet of the PWR and overburden observation wells. The groundwater from both the PWR and overburden observation wells at both elevations was clear and did not have any evidence of petroleum contamination. Bailer samples were periodically collected from the top 5 feet and bottom 5 feet of well MW-13S. The top 5 feet of water column was consistently clear. However, the bottom 5 feet had a color similar to kerosene and contained suspended tar stringers that were subsequently removed as described in Section 8.1.5. If sodium hydroxide injected in the PWR was involved in mobilizing the MGP wastes, less of it would be available for overcoming residual matrix acidity. Under these circumstances, the pH would tend to remain slightly acidic or neutral.

Diversion of the amendment from the fractures where the PWR observation wells are screened may have also contributed to the lack of change in pH. Although mounding along the line of wells OR 3S, OR 5S, and OR 10S indicated hydraulic connection, field data for conductivity indicated that a significant amount of the injectate was not moving in these fractures. Data in Table 9 indicates very elevated conductivities in the shallow overburden observation wells within 10 feet of the injection point during the initial week of injection. One week after the completion of shallow overburden zone injections, conductivities in the PWR wells were also elevated (Table 9). During the three weeks of injection, conductivities did not change significantly at wells OS 5S or OS 10S. The lack of change in conductivity at these wells over the course of the injections suggests that these wells are not as hydraulically connected with the injection point as the wells along the western axis.

Fracture trace analysis and geophysical testing were conducted prior to the installation of the PWR observation wells to determine the optimal orientation of the well field with respect to the location of water bearing fractures. Hydraulic connection was verified during well installation. It is possible that a fracture that was partially plugged with coal tar subsequently opened as a result of the shallow zone injections with that conduit diverting some amendment away from the PWR observation wells. It is believed that this fracture occurs somewhere in the vicinity of well MW-13S and MW-13 ISOC. The absence of any visual evidence of hydrocarbon contamination in the PWR and overburden observation wells coupled with the appearance of the coal tar in MW-13S supports this hypothesis. Additionally, this hypothesis is supported by field measurement of pH. The pH measured at well OR 3S was consistently been between 12.7 and 13.4, but the remaining PWR observation wells had pH values of 4.4 to 7.9. However, the pH at well MW-13 ISOC ranged from 9.7 to 12.6 during PWR injections, indicating that sodium hydroxide was reaching that well, but that it was not conveyed along the west axis line of PWR wells.

The negative ORP observed may have been a result of several interrelated mechanisms. Some research indicates that certain aluminate minerals are leached at low concentrations from silicate rock subjected to concentrated sodium hydroxide. Current research also indicates that certain iron containing minerals, such as goethite, catalyze formation of the superoxide radical from sodium persulfate. Catalytic formation of persulfate to form the superoxide radical is mineral specific so that certain iron containing minerals contribute to superoxide formation whereas other iron bearing minerals have no effect. Research indicating formation of the superoxide radical has generally been conducted at pH of 14. Although the pH at well OR 3S has ranged from 12.7 to 13.4, there may have been some mineral induced formation of the superoxide radical at this point in the formation.

Superoxide radical anion is believed to participate in Fenton's reagent reactions as part of the free radical propagation sequence in which hydroxyl radicals are formed. There is evidence that both reductant based and oxidant based free radical reactions are responsible for degradation of certain contaminants in Fenton's reagent based systems. A similar propagation sequence may be involved in the formation of sulfate and hydroxyl free radicals from sodium persulfate. Certain iron oxide minerals are also known to quench the formation of hydroxyl radicals or scavenge hydroxyl free radicals upon formation. Since hydroxyl radicals are believed to be involved in the generation of sulfate free radicals, it is possible that these combined effects occurred during the injection.

Additionally, if alumina or aluminates were being leached from the matrix concurrent with formation of the superoxide radical, those ions could potentially be reduced to zero valent aluminum, which would react with the sodium hydroxide forming trace levels of hydrogen. Hydrogen is also a powerful reducing agent and upon oxidation, yields the hydrogen ion which is responsible for acidity. As noted above, the pH observed in PWR observations wells was slightly acidic.

Based on these considerations, it was decided to alter the activator to hydrogen peroxide.

8.1.5 Removal of DNAPL from Monitoring Well MW-13S

In order to address the occurrence of DNAPL in MW-13S, a multi-phase extraction (MPE) event was conducted on August 1, 2013. The MPE event was conducted prior to completing the PWR ISCO using hydrogen peroxide as the activator to utilize MW-13S as a monitoring point.

A trailer mounted MPE system powered by a mobile diesel generator was used to perform the MPE event. The extraction system included a liquid ring vacuum pump, oil-water separator, and an activated carbon water treatment system. The extraction was conducted using one inch well casing placed approximately 1 ft. into the water table. The well head was sealed using a well cap with a 1 inch orifice and ports for vacuum gages. The well head was connected to the extraction system by 2 inch vacuum hose, where extracted groundwater was captured in a knock out tank and vapors were vented to the atmosphere. Extracted groundwater was transferred by a centrifugal pump and rubber hose to a HDPE tote, bypassing the oil-water separator and treatment system. The tote was properly disposed of concurrent with purge water from groundwater sampling events.

Vacuum gages were monitored throughout the MPE event on the 1 inch well casing, MW-13S well head, the inlet of the knock-out, and at the vacuum pump. Vacuum on the 1 inch casing fluctuated between 8 to 10 inches of mercury (in Hg). The vacuum gauge located at the wellhead measured the vacuum in the well annulus of MW-13S, which steadily increased from 40 inches of water to 60 inches of water as the MPE event proceeded. The vacuum observed at the knock-out tank varied between 10-12 in Hg. Vacuum measured at the liquid ring pump steadily increased from 19 in Hg at the beginning of the MPE event to the pump’s maximum rating of 25 in Hg at the end of the event.

Prior to the MPE event, a bailer sample was taken from the bottom 5 feet of MW-13S and visually monitored for DNAPL and suspended solids through a sight-tube located at the inlet of the knock-out tank. Initially, the water contained significant amounts of brown suspended solids, but DNAPL was not observed. After 30 minutes of extraction, the water was clear with no suspended solids or DNAPL observed. DNAPL was not observed and the water remained clear for another 1.5 hours of extraction. The MPE event had a duration of 2 hours, in which approximately 280 gallons of water was extracted. The aquifer was allowed to recharge to static conditions over a period of 2 hours before bailer samples from MW-13S was taken. The bailer samples were clear indicating that the DNAPL was no longer present in MW-13S. Field observations recorded during the event are provided in Appendix H.

8.1.6 PWR Hydrogen Peroxide Injection Zone Initial Conditions

Oxidant dosing for the remaining PWR pilot test injection utilized hydrogen peroxide as an activator and the remainder of the sodium persulfate that had not been used in the previous three weeks of injection.

The remaining sodium persulfate not used in the initial PWR injections was 1,925 lbs which was injected as approximately 1,010 gallons of 20% solution. Based on stoichiometric requirements and an estimated excess for native activator demand, approximately 2,640 gallons of 7% hydrogen peroxide was determined to be needed as activator.

Due to the limited porosity of the PWR, the total volume of the reagents was planned to be injected in three separate events that were implemented approximately one week apart. Each separate event involved injection of one third of the total reagent volume (approximately 1,220 gallons).

8.1.7 PWR Hydrogen Peroxide Injection Zone Conditions Process

The PWR zone ISCO injection process utilizing hydrogen peroxide as the activator was the same as the process used for the alkaline activated injection process. Hydrogen peroxide was delivered to the injection well utilizing the same metering pump used in previous injections. The two solutions were injected simultaneously at flow rate between 0.5 to 1 gpm, at a ratio of 2.6 to 1 of 7% hydrogen peroxide to sodium persulfate solution. The fluid delivery pressure varied from 5 to 10 psi dependent on the flow rate.

Prior to fully implementing the use of hydrogen peroxide as an activator in the PWR zone, a trial injection was conducted to evaluate whether a Fenton’s type reaction would occur due to natural iron-based minerals. Additionally, this action was taken as a safety precaution because hydrogen peroxide catalyzed oxidation is strongly exothermic and is often accompanied by significant gas and heat generation. This test was a one-day event conducted August 15, 2013. The test involved injection of 120 gallons of 7% hydrogen peroxide at 0.75 gpm.

Prior to starting the injection, geochemical parameters were measured in the PWR observation wells. Prior to initiating the peroxide test injection, DO and ORP averaged 2.7 mg/L and 400 mV, respectively. Pressures observed at the injection well and PWR observation wells nearest the injection well were very low (less than 5 psi) throughout the injection. Significant increases in temperature were not observed during the test injection indicating that a Fenton’s reaction did not occur at these conditions. Both temperature and pressure in the observation wells were consistent with those observed during the alkaline activated injections at this flow rate. Upon completion of the test injection, some increase had occurred in DO levels, but ORP values were consistent with those observed prior to the test.

Groundwater parameters were measured in the PWR observation wells periodically during injection to monitor the effectiveness and distribution of the injected reagents. Geochemical parameters were also monitored in select shallow observation wells periodically to determine if they were influenced by the PWR ISCO injection. DO and ORP are the primary indicators of successful oxidation reaction occurring in groundwater when using hydrogen peroxide as an activator.

The geochemical data from monitoring during peroxide activated injection in the PWR are included in Appendix I. The volume of injected sodium persulfate solution and hydrogen peroxide is shown by day, including comments on the injection process in Table 14.

8.1.8 PWR Hydrogen Peroxide Injection Zone Conditions

Week 1 Injection – August 19, 2013

In the first week of peroxide activated injections into the PWR zone, 54 gallons of persulfate solution and 125 gallons of hydrogen peroxide were injected simultaneously at ratio of 2.6 to 1, respectively. Initial geochemical parameters in the PWR observation wells indicated an oxidizing environment with ORP values of 160 to 524 mV. Acidic to slightly acid pH values were observed, ranging from 3.35 to 6.52 SU. Well OR 3S had a DO level of 3.14 mg/L. Wells OR 3W and OR 5W had DO levels of 14.32 mg/L and 2.74 mg/L, indicating influence from the peroxide test injection conducted in the prior week. All other PWR observation wells had DO concentrations of less than 2.0 mg/L.

Prior to starting the peroxide activated injection, shallow observation wells OS 10S, OS 15S, and OS 20S displayed DO levels greater than 11.0 mg/L. These DO readings were significantly above the levels observed in March and April 2013 (Table 9) and indicated influence from the peroxide test injection in the overburden. Wells OS 10S and OS 15S had ORP values of 553 and 494 mV, respectively. These DO and ORP readings were significantly above the measurements in July, which averaged 128 mV and indicated the influence of the peroxide test injection.

At the conclusion of the first week of injection operations, ORP values increased significantly in all PWR observation wells, ranging from 408 to 518 mV (Appendix J). ORP also increased from a mean of -17 mV at MW-13S and MW-13 ISOC to 54 mV at these wells. DO levels increased in OR 3S, OR 3W, MW-13S, and MW-13 ISOC. These

Table 14. Summary of PWR Peroxide Activated Injection Activities

Date	Sodium Persulfate Solution Injected (gal)	Hydrogen Peroxide Injected (gal)	Comments
Week 1			
8/19/2013	54	125	Simultaneously injected 2.6:1 peroxide to persulfate ratio.
8/20/2013	190	310	Simultaneously injected 2.6:1 peroxide to persulfate ratio. Flow meter for the persulfate reading lower than visual observations. Stopped injecting persulfate at 13:00 (190 gal) and continued to inject peroxide. Noticed excessive mounding and pressure at MW-13 ISOC after two hours of injecting just peroxide. Stopped injecting peroxide at 14:50 (310 gal).
8/21/2013	90	445	Simultaneously injected 2.6:1 peroxide to persulfate ratio. Injected peroxide for two hours at 1 gpm (~105 gal) before starting persulfate. Flow meter for the persulfate not reading low flow rates. Persulfate injection total calculated from visual observations. Pressure at the wellhead on wells OR 10S and OS 20S.
Total	334	880	
Week 2			
8/26/2013	95	252	Injected 2.6:1 peroxide to persulfate ratio. Noticed pressure at OS 20S wellhead. Excessive mounding at all wells except MW-13 SOC. Persulfate flow meter not reading low flow amounts and the injection total was calculated from visual observations.
8/27/2013	112	295	Injected 2.6:1 peroxide to persulfate ratio.
8/28/2013	125	330	Injected 2.6:1 peroxide to persulfate ratio. Flow meter on the peroxide injection pump not reading accurately. Pumping at a higher rate than the flow meter is showing. Injected persulfate an additional 30 minutes at the end of the day to maintain 2.6 to 1 ratio.
Total	332	877	
Week 3			
9/3/2013	50	125	Simultaneously injected 2.6:1 peroxide to persulfate ratio. Noticed mounding at all wells (more than 2 feet) at OR 3S, MW-13S, OS 10S, OS 15S, OS 20S, and OS 25S.
9/4/2013	85	215	Simultaneously injected 2.6:1 Hydrogen peroxide to persulfate ratio.
Week 3 Total	135	340	
Grand Total	**801**	**2,097**	

Notes: gal = gallons
gpm = gallons per minute

changes indicated that an oxidizing environment was created near the injection well. The increased DO and ORP at MW-13S and MW-13 ISOC further suggested that there are open fracture(s) in the vicinity which provided a pathway for diverting amendment from the PWR observation well MW-13 ISOC.

Excessive mounding and off gassing was observed in MW-13 ISOC in the second day of injections. Injection activities were temporarily stopped for the water level to recede and a well cap equipped with a small needle valve and pressure indicator was installed to monitor pressure and vent the well when necessary.

Week 2 Injection – August 26, 2013

A total of 877 gallons of hydrogen peroxide and 332 gallons of sodium persulfate were injected in the second week of operation. Pressure on the PWR and shallow observation wells was routinely monitored using a 2-inch well cap equipped with drop tube, needle valve, and pressure gauge.

DO levels in the PWR wells were very elevated during the second week of injection with levels exceeding 30 mg/L at wells OR 3S and OR 3W. These values exceeded the theoretical solubility limit for oxygen in water indicating a super saturated condition accompanied by gas evolution at these wells. Elevated DO levels were also measured at well OR 5W, and the DO increased from 0.7 to 2.06 mg/L at well OR 10W. However, DO levels did not increase significantly in wells OR 5S or OR 10S. At the end of the second week of injection, ORP levels averaged 458 mV in the PWR wells indicating an extremely oxidative environment.

The shallow observation wells began to exhibit a buildup of pressure of less than 1 psi during the second week. This corresponded with a significant increase in DO levels at wells OS 10S, OS 15S, and OS 20S of greater than 20 mg/L. Elevated DO levels were also observed at wells MW-13S and MW-13 ISOC. These observations indicated that the injections in the PWR zone resulted in oxygen transfer to the shallow zone and eventually into the atmosphere.

Week 3 Injection – September 3, 2013

In the third week of injection operations, 340 gallons of hydrogen peroxide and 135 gallons of sodium persulfate were injected. As the injections progressed in the third week, mounding in excess of 2 feet was observed in all of the shallow observation wells and at OR 3S. In order to address this condition, the injection would be halted temporarily (typically less than 30 minutes) to allow mounding to recede.

Geochemical conditions during the week were consistent with prior measurements. DO levels of approximately 20 mg/L continued to be observed at wells OR 3S, OR 3W, and MW-13 ISOC. A significant increase in DO from 3.09 to 6.25 mg/L was observed at well OS 10W. DO levels above saturation continued to be observed at shallow observation wells OS 10S, OS 15S, and OS 20S. Highly positive ORP readings were noted in all PWR observation wells. Shallow observation wells OS 10S, OS 15S, and OS 20S continued to display very positive ORP values of 100 to 550 mV.

8.2 PWR Zone Injection Monitoring

The pilot ISCO Injection for the PWR zone included seven sampling events and generated a significant amount of data. The monitoring program has three key components: (1) monitoring baseline conditions, (2) measuring oxidant delivery effectiveness, and (3) evaluating contaminant treatment efficacy. The pilot test results are discussed in terms of the MGP contaminants of interest, reduction-oxidation state indicators (DO, ORP) and reduction-oxidation sensitive metals (manganese and arsenic). The remaining analytes that are not indicative of treatment effectiveness are included in the data tables, but not discussed. Laboratory reports are included in Appendix K. Field reports recording geochemical parameters measured as part of performance monitoring are included in Appendix J. Table 15 summarizes the baseline and performance sampling matrix.

Initial sampling to develop the baseline for performance monitoring was conducted October 3 - 5, 2012. Between February 27 and 28, 2013, AMEC personnel conducted groundwater sampling for the set of parameters specified in the Work Plan. These parameters established the effectiveness of the overburden injections on both the shallow zone and PWR. Seventeen groundwater wells were sampled in this event concurrent with the site-wide semi-annual groundwater monitoring event. Of those 17 wells, 3 downgradient monitoring wells (MW-13S, MW-13D, and MW-13 ISOC), 8 shallow (overburden) wells, and 6 PWR wells were included. Prior to collection of the sample from each monitoring well, field measurement of pH, turbidity, DO, and ORP was performed. The baseline parameters included VOCs, SVOCs, metals, sulfate, and TPH.

Prior to sample collection, the monitoring well identification, time, and date were recorded on the respective groundwater sampling field form. Groundwater samples were collected as described in Section 7.2.

The PWR zone injection into the weathered rock began on March 4, 2013 and was completed on March 21, 2013. Following the injection, a 5-week monitoring program was initiated. The bi-weekly monitoring program included synoptic groundwater level measurement near the pilot study area, water quality data measurements with a YSI water quality monitoring system, and field test kit analysis of persulfate concentrations to evaluate oxidant delivery.

Table 15. PWR Performance Monitoring Network and Parameters

MONITORING NETWORK AND PARAMETERS				
Frequency	**Monitoring Wells**	**Quality Control Samples**	**Parameter**	**Analytical Method**
Baseline/Semi-Annual Event *(February 27-28, 2013)*	Overburden Observation Wells* PWR Observation Wells** Semi-annual Network Wells***	(2) Trip Blanks (1) Duplicate	VOCs SVOCs Sulfate TPH Metals	Method 8260B Method 8270C Method 9056 Method 8015B-PHI Method 6010B or Method 6020
BEDROCK INJECTION MONITORING				
Frequency	**Monitoring Wells**	**Quality Control Samples**	**Parameter**	**Analytical Method**
PWR Injection: Week 1 *(March 25-29, 2013)*	PWR Observation Wells** MW-13 ISOC OS-5E, OS-10E OS-5S, OS-10S, OS-15S, OS-20S	(1) Trip Blank	VOCs SVOCs Sulfate TPH Metals	Method 8260B Method 8270C Method 300.0 Method 8015B-PHI Method 6010B or Method 6020
PWR Injection: Week 3 *(April 8-12, 2013)*	PWR Observation Wells** MW-13 ISOC OS-5E, OS-10E OS-5S, OS-10S	NA	Persulfate pH, DO, ORP conductivity turbidity	Klozur® persulfate field test kit YSI Model 6920 or equivalent YSI Model 6920 or equivalent YSI Model 6920 or equivalent
PWR Injection: Week 5 *(April 22-26, 2013)*	PWR Observation Wells** MW-13 ISOC OS-5E, OS-10E OS-5S, OS-10S, OS-15S	NA	Persulfate pH, DO, ORP conductivity turbidity	Klozur® persulfate field test kit YSI Model 6920 or equivalent YSI Model 6920 or equivalent YSI Model 6920 or equivalent

Table 15. PWR Performance Monitoring Network and Parameters (Continued)

BEDROCK INJECTION MONITORING CONTINUED				
Frequency	**Monitoring Wells**	**Quality Control Samples**	**Parameter**	**Analytical Method**
Semi-Annual Event: Week 19 *(July 29 – August 2, 2013)*	Overburden Observation Wells* PWR Observation Wells** Semi-annual Network Wells***	(2) Trip Blanks (2) Duplicates	VOCs SVOCs Nitrate Sulfate Iron Manganese Alkalinity	Method 8260B Method 8270C Method 9056 Method 9056 Method 6010B or Method 6020 Method 6010B or Method 6020 Method 310.2
PWR Injection: Week 25 *(September 9-13, 2013)*	Overburden Observation Wells* PWR Observation Wells** MW-13 ISOC	(1) Trip Blank	Persulfate VOCs SVOCs Sulfate TPH Metals	Klozur® persulfate field test kit Method 8260B Method 8270C Method 300.0 Method 8015B-PHI Method 6010B or Method 6020
PWR Injection: Week 26 *(September 16-20, 2013)*	Overburden Observation Wells* PWR Observation Wells** MW-13 ISOC	NA	pH, DO, ORP conductivity turbidity	YSI Model 6920 or equivalent YSI Model 6920 or equivalent YSI Model 6920 or equivalent
PWR Injection: Week 28 *(September 30-October 4, 2013)*	PWR Observation Wells** MW-13 ISOC OS-10E, OS-10S, OS-15S	(1) Trip Blank	VOCs SVOCs TPH	Method 8260B Method 8270C Method 8015B-PHI

* Overburden Observation Wells – OS-5N, OS-5E, OS-10E, OS-5S, OS-10S, OS-15S, OS-20S, OS-25S

** PWR Observation Wells – OR-3W, OR-5W, OR-10W, OR-3S, OR-5S, OR-10S

*** Semi-annual Network Wells – Overburden: MW-1SS, MW-2SS, MW-3SS, MW-10S, MW-11S, MW-12S, MW-13S, MW-14S, MW-15S, MW-16S, MW-17S, MW-18S, MW-19-S; Bedrock: MW-10D, MW-11D, MW-12D, MW-13D, MW-14D, MW-15D, MW-16D, MW-18D, MW-1DR; PWR: MW-13 ISOC

Notes:
DO = dissolved oxygen
NA = not applicable
ORP = oxidation-reduction potential
PWR = partially weathered rock
SVOC = semivolatile organic compound
TPH = total petroleum hydrocarbons
VOC = volatile organic compound

On March 27 and 28, 2013, the initial groundwater performance sampling event for collection of VOC and SVOC data was conducted. This event included collection of groundwater samples from all PWR observation wells and eight shallow monitoring wells (MW-13S, MW-13 ISOC, OS 5E, OS 10E, OS 5S, OS 10S, OS 15S, and OS 20S). One trip blank sample was collected for quality control purposes. Prior to well purging, depth to water was measured to the nearest 0.01 foot at each well using an electric water-level indicator. All groundwater level measurements were made relative to an established reference point on the well casing. The field water quality perimeter measurements of specific conductance, temperature, DO, ORP, turbidity, and pH were collected during purging using a YSI Model 6920 multi-parameter sonde with a Model 650 MDS display. Field analysis of persulfate concentrations were collected using a Hach persulfate field test kit. Samples were collected using a peristaltic pump with new or dedicated polyethylene tubing for each well at a flow rate of approximately 250 milliliter per minute or less, such that the drawdown of the water level within the monitoring well did not exceed the maximum drawdown. Groundwater samples were collected directly into laboratory-supplied sample containers from the pump discharge. Groundwater samples were analyzed for VOCs (EPA Method 8260B), SVOCs (EPA Method 8270C), sulfate (EPA Method 300.0), metals (EPA Method 6010), and TPH (EPA Method 8015). Samples were not filtered in the field. These groundwater performance events were repeated on July 30 and 31 as part of the site-wide semi-annual event and on September 12, 2013. A final performance sampling event was conducted on October 3, 2013 that included only the PWR observation wells, MW-13 ISOC, and a limited set of shallow wells observation wells (OS 10E, OS 10S and OS 15S).

On April 9, 2013, the initial groundwater performance geochemical monitoring was performed. This event included collection of groundwater quality measurements made in general accordance with EPA Region IV standard operating procedures for field sampling. The field groundwater quality measurements of specific conductance, temperature, DO, ORP, turbidity, and pH were collected using a YSI Model 6920 multi-parameter sonde with a Model 650 MDS display. Field analysis of persulfate concentrations were collected using a Klozur® persulfate field test kit. These field measurement only events were repeated on April 23, July 30 to August 1 during the semi-annual event, and September 20, 2013. Groundwater field measurements and sampling comments were recorded on field logs (Appendix J).

8.3 PWR Zone Injection Performance Monitoring Results

8.3.1 Baseline Conditions

The results for the field measured parameters (DO, ORP, and pH) are provided in Table 16. The concentrations of VOCs, SVOCs, and TPH from the performance sampling events are provided in Table 17 and Table 18. Metals results are summarized in Table 19.

DO concentrations measured in the baseline event ranged from 0.00 to 8.9 mg/L with an average of 2.76 mg/L. ORP values measured in the baseline event ranged from -453 to 221 mV with an average of -161 mV. Observations of pH average 6.24 SU.

The baseline sampling results of the PWR wells indicated BTEX and TPH-GRO concentrations lower than at MW-13 ISOC. Other alkyl benzenes and naphthalene concentrations in the PWR observation wells were consistent with concentrations observed at MS-13 ISOC. Methyl naphthalenes, PAHs, and TPH-DRO concentrations were similar to those observed at MW-13 ISOC during this event, but the PAH and TPH-DRO concentrations were several times greater than previously estimated from historic data.

8.3.2 Evaluation of Oxidant Delivery

Oxidant delivery effectiveness was monitored by the collection of the Klozur® and Hach persulfate kits and measurements of DO, ORP, pH, and specific conductance during injection monitoring and the field-only events of which there were scheduled to be three following the injection.

The PWR injections were stopped during the week of March 18, 2013 and the final injection monitoring event during that week was on March 21, 2013. Along the south line of injection wells (OR 3S to OR 10S), the final DO and ORP measurements averaged 5.6 mg/L and -271 mV. As previously noted, a significant increase in pH from 6.9 to 13 SU was noted at OR 3S. Specific conductance also increased significantly at OR 3S during the three weeks of hydroxide activated persulfate injections. No significant changes in either pH or specific conductance were observed at either OR 5S or OR 10S during the injections. Field sampling results for geochemical parameters on March 27, 2013 also found elevated pH at well OR 3S. During the March 27 sampling event, the DO measurements along the south axis wells averaged 1.6 mg/L, which was a decrease relative to the levels observed during injection. However, ORP along this axis of wells had increased from an average of -271 to 252 mV indicating a return to oxidative conditions observed a the completion of the overburden injections.

Table 16. Results for Geochemical Parameters – PWR Performance Monitoring

Monitoring Well	Date Sampled	pH	ORP (mV)	DO (mg/L)
MW-13 ISOC	02/28/13	6.10	152	0.00
	03/27/13	6.76	150	10.90
	04/09/13	6.64	225	0.00
	04/23/13	6.68	-15	0.00
	07/31/13	9.68	104	0.00
	09/12/13	5.36	152	2.51
	09/20/13	5.62	71	0.00
	10/03/13	5.89	59	1.38
OS 5N	02/28/13	5.97	140	3.25
	07/30/13	6.40	156	2.78
	09/12/13	5.64	329	3.32
	10/03/13	6.42	228	1.01
OS 5S	02/28/13	8.32	224	14.75
	03/28/13	9.64	220	16.41
	04/09/13	8.02	338	6.02
	04/23/13	5.36	241	4.91
	07/30/13	9.69	-25	3.99
	09/12/13	6.63	289	2.03
	09/20/13	6.29	122	0.80
	10/03/13	6.25	267	1.48
OS 5E	02/28/13	6.79	137	16.97
	03/28/13	7.09	448	23.35
	04/09/13	7.04	296	8.84
	04/23/13	6.87	197	13.35
	07/30/13	7.07	112	6.05
	09/12/13	7.10	185	4.75
	09/20/13	7.09	116	4.31
	10/03/13	6.72	199	2.49
OS 10S	02/28/13	6.28	119	0.00
	03/27/13	5.11	421	0.55
	04/09/13	5.00	453	4.69
	04/23/13	5.36	258	0.00
	07/30/13	5.70	137	0.17
	09/12/13	4.20	454	4.38

Table 16. Results for Geochemical Parameters – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	pH	ORP (mV)	DO (mg/L)
OS 10S Continued	09/20/13	4.36	341	3.61
	10/03/13	4.33	4	5.83
OS 10E	02/28/13	6.99	96	0.47
	03/28/13	6.78	348	2.48
	04/09/13	6.79	182	7.46
	04/23/13	6.95	142	6.12
	07/30/13	6.87	109	1.66
	09/12/13	6.85	32	0.18
	09/20/13	6.66	-47	0.00
	10/03/13	6.84	207	2.08
OS 15S	02/28/13	7.11	68	5.11
	03/27/13	6.17	158	0.00
	04/23/13	5.52	249	0.00
	07/30/13	6.20	120	0.52
	09/12/13	3.78	438	5.08
	09/20/13	3.75	416	7.87
	10/03/13	3.87	396	5.80
OS 20S	02/28/13	6.55	74	2.65
	03/27/13	6.34	91	0.00
	07/30/13	6.39	82	2.54
	09/12/13	5.76	35	2.21
	09/20/13	5.80	8	3.87
	10/03/13	6.36	2	2.25
OS 25S	02/28/13	5.31	62	0.89
	07/31/13	6.35	-64	0.77
	09/12/13	6.24	-57	0.62
	09/20/13	6.28	-70	0.53
	10/03/13	6.38	-72	0.18

Table 16. Results for Geochemical Parameters – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	pH	ORP (mV)	DO (mg/L)
OR 3S	02/28/13	6.90	204	0.00
	03/27/13	12.89	183	2.96
	04/09/13	9.14	378	7.36
	04/23/13	7.11	209	11.85
	07/30/13	6.61	301	6.32
	09/12/13	6.34	205	8.95
	09/20/13	6.32	167	6.35
	10/03/13	6.07	268	11.30
OR 3W	02/28/13	6.10	248	1.38
	03/27/13	3.85	555	9.03
	04/09/13	4.85	487	3.66
	04/23/13	5.42	293	0.98
	07/30/13	6.57	368	10.47
	09/12/13	6.29	368	14.78
	09/20/13	6.66	211	16.63
	10/03/13	6.07	268	11.30
OR 5S	02/28/13	6.69	92	2.43
	03/27/13	6.58	308	0.51
	04/09/13	6.44	335	7.59
	04/23/13	6.72	187	3.82
	07/30/13	6.56	296	1.16
	09/12/13	6.95	98	0.00
	09/20/13	6.49	135	1.11
	10/03/13	6.44	147	6.95
OR 5W	02/28/13	5.84	258	0.94
	03/27/13	6.54	368	7.79
	04/09/13	5.92	387	5.43
	04/23/13	6.01	248	3.58
	07/30/13	3.46	538	0.10
	09/12/13	3.80	507	0.89
	09/20/13	3.60	469	0.00
	10/03/13	4.35	387	2.34

Table 16. Results for Geochemical Parameters – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	pH	ORP (mV)	DO (mg/L)
OR 10S	02/28/13	6.19	230	6.21
	03/27/13	5.16	345	0.96
	04/09/13	4.57	479	5.31
	04/23/13	3.44	457	0.00
	07/30/13	3.56	472	0.00
	09/12/13	3.85	439	0.00
	09/20/13	4.03	404	10.80
	10/03/13	5.18	252	2.01
OR 10W	02/28/13	5.84	275	1.65
	03/27/13	5.65	365	0.29
	04/09/13	12.08	115	7.47
	04/23/13	5.24	265	0.10
	07/30/13	3.12	578	0.69
	09/12/13	3.28	539	1.61
	09/20/13	4.82	388	2.10
	10/03/13	4.02	386	2.18

Notes: DO = dissolved oxygen
mg/L = milligrams per liter
mV = millivolt
ISCO = in-situ chemical oxidation
ORP = oxidation reduction potential
PWR = partially weathered rock

Table 17. Results for Volatile Organic Compounds – PWR Performance Monitoring

Monitoring Well	Date Sampled	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone (MEK)	Acetone	Benzene	Bromomethane	Carbon Disulfide	Chloroform	Chloromethane	Ethylbenzene	Isopropylbenzene	Methylene chloride	Naphthalene	n-Butylbenzene	n-Propylbenzene	p-Isopropyltoluene	Styrene	Toluene	Xylenes, total	Gasoline Range Organics
	RBSL	--	--	--	--	--	--	--	5	--	--	--	--	700	--	--	25	--	--	--	--	1,000	10,000	--
MW-13S	10/03/12	<1.00	<5.00	<1.00	**118**	**41.9**	<50.0	<50.0	**247**	<1.00	<1.00	<1.00	<1.00	**116**	**15.9**	<5.00	**714**	**9.07**	**7.58**	**4.15**	<1.00	**32.1**	**99.9**	**1,510**
	02/27/13	<20.0	<20.0	<20.0	**143**	**36.1**	<1000	<1000	**25.7**	<20.0	<20.0	<20	<20.0	**88.3**	<20.0	<100	**2,290**	<20.0	<20.0	<20.0	<20.0	<20.0	<60.0	**1,450**
	03/28/13	<20.0	<20.0	<20.0	**437**	**142**	<1000	<1000	**34.5**	<20.0	<20.0	<20	<20.0	**124**	**34.9**	<100	**3,040**	**44.5**	<20.0	**21.9**	<20.0	**77.5**	**277**	**2,220**
	07/30/13	<1.00	<1.00	<1.00	**105**	**39.8**	<50.0	**10**	**557**	<1.00	<1.00	<1.00	<1.00	**124**	**7.88**	<5.00	**2,400**	**3.12**	<1.00	**2.22**	**51.6**	**155**	**259**	**4,730**
MW-13D	10/03/12	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	**618**
	02/27/13	**1.09**	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	**5.62**	<1.00	<1.00	<1.00	<1.00	**1.17**	<1.00	<5.00	**9.46**	<1.00	<1.00	<1.00	<1.00	**3.96**	<3.00	<100
	07/30/13	**1.19**	**1.07**	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
MW-13 ISOC	10/03/12	<1.00	<1.00	<1.00	**110**	**43.7**	<50.0	<50.0	**667**	<1.00	<1.00	<1.00	<1.00	**328**	**15.2**	<5.00	**736**	**3.66**	**6.64**	**1.59**	<1.00	**45.4**	**225**	**2,180**
	02/27/13	<1.00	<1.00	**12**	**110**	**35.6**	<50.0	**81.4**	**495**	<1.00	<1.00	<1.00	<1.00	**129**	**3.21**	<5.00	**1,430**	**1.38**	**2.25**	**1.28**	**58.2**	**476**	**446**	**4,700**
	03/27/13	<1.00	<1.00	<1.00	**136**	**46.9**	<50.0	**97.3**	**720**	<1.00	1.66	<1.00	<1.00	**143**	**3.35**	<5.00	**1,130**	<1.00	**1.86**	**1.9**	**50.2**	**567**	**672**	**4,500**
	07/31/13	<1.00	<1.00	<1.00	**34.5**	**9.77**	<50.0	**13.9**	**114**	<1.00	<1.00	<1.00	<1.00	**37.6**	**4.64**	<5.00	**404**	<1.00	**1.97**	**1.03**	**1.71**	**16.6**	**41.4**	**629**
	09/12/13	<1.00	<1.00	<1.00	**5.73**	**3.19**	<50.0	<5.00	**6.62**	<1.00	**4.26**	**2.84**	<1.00	**8.97**	<1.00	<5.00	**45.2**	<1.00	<1.00	<1.00	<1.00	**3.31**	**10.9**	<100
	10/03/13	<1.00	<1.00	<1.00	**5.92**	**2.34**	<50.0	<5.00	**13.6**	<1.00	<1.00	**1.98**	<1.00	**6.26**	<1.00	<5.00	**70.6**	<1.00	<1.00	<1.00	<1.00	**2.19**	**10.2**	**108**
OS 5N	10/05/12	<1.00	<1.00	<1.00	**28.1**	**8.89**	<50.0	<50.0	**3.41**	<1.00	<1.00	<1.00	<1.00	**18.7**	**4.62**	<5.00	**258**	<1.00	**2.01**	**1.26**	<1.00	<1.00	**13.4**	**246**
	02/28/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	**1.0**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**11.9**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OS 5S	10/05/12	<1.00	<1.00	<1.00	**147**	**43.6**	<50.0	<50.0	**8.80**	<1.00	<1.00	<1.00	<1.00	**105**	**21.7**	<5.00	**2,660**	<1.00	**10.1**	**6.59**	<1.00	**1.74**	**80.6**	**1,600**
	02/28/13	<1.00	<1.00	<1.00	**3.09**	**1.13**	<50.0	**519**	<1.00	**29.8**	**1.91**	<1.00	**42.8**	**4.92**	**2.5**	<5.00	**43**	**1.05**	**1.22**	**1.19**	<1.00	<1.00	<3.00	<100
	03/28/13	<1.00	<1.00	<1.00	**1.14**	<1.00	**73.2**	**881**	**1.59**	**51.4**	**2.8**	<1.00	**75.3**	**5.3**	**2.31**	<5.00	**226**	<1.00	**1.1**	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**37.4**	<1.00	**2.4**	<1.00	<1.00	**3.5**	<1.00	<1.00	<5.00	**12.8**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**62.2**	<1.00	**7.07**	**1.31**	<1.00	**8.53**	<1.00	<1.00	<5.00	**20.3**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100

Table 17. Results for Volatile Organic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone (MEK)	Acetone	Benzene	Bromomethane	Carbon Disulfide	Chloroform	Chloromethane	Ethylbenzene	Isopropylbenzene	Methylene chloride	Naphthalene	n-Butylbenzene	n-Propylbenzene	p-Isopropyltoluene	Styrene	Toluene	Xylenes, total	Gasoline Range Organics
	RBSL	--	--	--	--	--	--	--	5	--	--	--	--	700	--	--	25	--	--	--	--	1,000	10,000	--
OS 5E	10/05/12	<1.00	<1.00	<1.00	**8.93**	**2.36**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	**3.2**	**1.21**	<5.00	**166**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	02/28/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	**1.73**	<1.00	<1.00	**2.48**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	03/28/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**9.8**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OS 10S	10/05/12	<1.00	<1.00	<1.00	**114**	**37.6**	<50.0	<50.0	**4.33**	<1.00	<1.00	<1.00	<1.00	**66.8**	**16.6**	<5.00	**1,760**	<1.00	**7.61**	**5.96**	<1.00	**1.03**	**50.7**	**1,200**
	02/28/13	<1.00	<1.00	<1.00	**22.3**	**1.48**	<50.0	**210**	<1.00	**26.2**	**3.03**	<1.00	**26.9**	**8.19**	**3.11**	<5.00	**309**	<1.00	**1.73**	**2.6**	<1.00	<1.00	**5.79**	**120**
	03/27/13	<1.00	<1.00	<1.00	**3.41**	<1.00	<1.00	**130**	<1.00	**30.5**	**1.97**	<1.00	**36.9**	**4.12**	**1.8**	<5.00	**208**	<1.00	**1.00**	**1.25**	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	**22**	**2.4**	<50.0	**28.8**	**1.48**	<1.00	**1.63**	<1.00	**2.61**	**6.39**	**3.27**	<5.00	**263**	<1.00	**1.85**	<1.00	<1.00	<1.00	<2.00	**105**
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**23.4**	<1.00	<1.00	**1.15**	<1.00	<1.00	<1.00	<1.00	<5.00	**48.9**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	10/03/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**12.7**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OS-15S	10/05/12	<1.00	<1.00	<1.00	**66.9**	**25.4**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	**18.2**	**8.12**	<5.00	**756**	<1.00	**5.22**	**4.83**	<1.00	<1.00	**12.4**	**364**
	02/28/13	<1.00	<1.00	<1.00	**3.65**	**1.84**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.0	<1.0	<5.00	**15.1**	<1.00	<1.00	<1.0	<1.00	<1.00	<3.00	<100
	03/27/13	<1.00	<1.00	<1.00	**9.08**	**3.61**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**65.1**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	**1.84**	<1.00	<50.0	**23**	<1.00	<1.00	**4.58**	**2.43**	<1.00	**1.61**	<1.00	<5.00	**46.4**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	**834**
	10/03/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	**1.23**	**2.21**	<1.00	<1.00	<1.00	<5.00	**8.74**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OS-20S	10/05/12	<1.00	<1.00	<1.00	**105**	**34.5**	<50.0	<50.0	**27.7**	<1.00	<1.00	<1.00	<1.00	**60**	**16.2**	<5.00	**2,430**	<1.00	**9.75**	**7.35**	<1.00	**2.53**	**49.5**	**1,170**
	02/28/13	<1.00	<1.00	<1.00	**26.9**	**4.17**	<50.0	**53.2**	**2.07**	<1.00	**10.2**	<1.00	<1.00	**21.1**	**6.69**	<5.00	**671**	**2.35**	**3.91**	**2.07**	<1.00	<1.00	**12.2**	**193**
	03/27/13	<1.00	<1.00	<1.00	**31**	**7.33**	<50.0	<50.0	**7.04**	<1.00	**4.49**	<1.00	<1.00	**15.6**	**5.27**	<5.00	**464**	**2.35**	**2.51**	**1.00**	<1.00	<1.00	**12.7**	**165**
	07/30/13	<1.00	<1.00	<1.00	**6.38**	**1.85**	<50.0	<5.00	**2.15**	<1.00	<1.00	<1.00	<1.00	**3.12**	<1.00	<5.00	**89.8**	<1.00	<1.00	<1.00	<1.00	<1.00	**2.66**	<100
	09/12/13	<1.00	<1.00	<1.00	**155**	**70.1**	<50.0	<5.00	**12.6**	<1.00	**17.4**	<1.00	<1.00	**98.1**	**22.2**	<5.00	**1,550**	<1.00	**9.83**	**4.85**	<1.00	**6.43**	**100**	**1,150**

Table 17. Results for Volatile Organic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone (MEK)	Acetone	Benzene	Bromomethane	Carbon Disulfide	Chloroform	Chloromethane	Ethylbenzene	Isopropylbenzene	Methylene chloride	Naphthalene	n-Butylbenzene	n-Propylbenzene	p-Isopropyltoluene	Styrene	Toluene	Xylenes, total	Gasoline Range Organics
	RBSL	--	--	--	--	--	--	--	5	--	--	--	--	700	--	--	25	--	--	--	--	1,000	10,000	--
OS-25S	10/05/12	<1.00	<1.00	<1.00	**48.9**	**24.8**	<50.0	<50.0	**19.8**	<1.00	<1.00	<1.00	<1.00	**35.6**	**10.1**	<5.00	**754**	<1.00	**6.52**	**2.94**	**1.24**	**1.32**	**28.7**	**796**
	02/28/13	<1.00	<1.00	<1.00	**21.1**	**2.73**	<50.0	<50.0	**27.4**	<1.00	**11.7**	<1.00	<1.00	**26.6**	**7.44**	<5.00	**732**	**2.69**	**4.8**	**1.84**	<1.00	<1.00	**10.1**	**276**
	07/31/13	<1.00	<1.00	<1.00	**41.6**	**20.3**	<50.0	<5.00	**30.4**	<1.00	<1.00	<1.00	<1.00	**35.1**	**9.03**	<5.00	**548**	<1.00	**5.68**	**2.07**	<1.00	<1.00	**12.9**	**523**
	09/12/13	<1.00	<1.00	<1.00	**60.5**	**29.1**	<50.0	<5.00	**29.6**	<1.00	**1.32**	<1.00	<1.00	**53**	**13.2**	<5.00	**8.5**	<1.00	**7.13**	**2.77**	<1.00	**1.06**	**25.5**	**581**
OR-3S	10/04/12	<1.00	<1.00	<1.00	**152**	**47.7**	<50.0	<50.0	**5.06**	<1.00	<1.00	<1.00	<1.00	**43.7**	**20.3**	<5.00	**1,670**	<1.00	**10.9**	**6.81**	<1.00	<1.00	**28.5**	**690**
	02/27/13	<1.00	<1.00	<1.00	**3.92**	<1.00	<50.0	<50.0	**1.69**	<1.00	<1.00	<1.00	<1.00	<1.00	**1.19**	<5.00	**78.9**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	03/27/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**82.6**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**10.5**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**7.86**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	10/03/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OR-3W	10/04/12	<1.00	<1.00	<1.00	**62.1**	**22.9**	<50.0	<50.0	**9.34**	<1.00	<1.00	<1.00	<1.00	**42.8**	**9.59**	<5.00	**532**	<1.00	**3.33**	**2.86**	<1.00	**3.94**	**36.4**	**509**
	02/28/13	<1.00	<1.00	<1.00	**19.1**	**3.91**	<50.0	<50.0	**1.54**	<1.00	**1.31**	<1.00	<1.00	**3.75**	**2.75**	<1.00	**4.52**	**1.77**	**1.18**	**1.11**	<1.00	<1.00	<1.00	**108**
	03/27/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**146**	<1.0	<1.00	**4.94**	**1.78**	**12.1**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**67.8**	<1.00	<1.00	**1.05**	<1.00	**2.53**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**86.3**	<1.00	<1.00	**1.78**	<1.00	**1.46**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	10/03/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**179**	<1.00	<1.00	**2.8**	<1.00	**1.46**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100

Table 17. Results for Volatile Organic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone (MEK)	Acetone	Benzene	Bromomethane	Carbon Disulfide	Chloroform	Chloromethane	Ethylbenzene	Isopropylbenzene	Methylene chloride	Naphthalene	n-Butylbenzene	n-Propylbenzene	p-Isopropyltoluene	Styrene	Toluene	Xylenes, total	Gasoline Range Organics
	RBSL	--	--	--	--	--	--	--	5	--	--	--	--	700	--	--	25	--	--	--	--	1,000	10,000	--
OR 5S	10/04/12	**1.01**	**1.11**	<1.00	**36.2**	**16.3**	<50.0	<50.0	**2.14**	<1.00	<1.00	<1.00	<1.00	**24.1**	**6.27**	<5.00	**420**	<1.00	**2.29**	**1.88**	<1.00	<1.00	**16**	**275**
	02/27/13	<1.00	<1.00	<1.00	**14.6**	**4.17**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	**5.47**	**2.18**	**39.4**	**96.6**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	**111**
	03/27/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**5.85**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	**6.71**	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	**1.77**	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	**1.07**	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	10/03/13	<1.00	<1.00	<1.00	**3.22**	**1.4**	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	**1.86**	<1.00	<5.00	**5.98**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OR-5S	10/04/12	**1.01**	**1.11**	<1.00	**36.2**	**16.3**	<50.0	<50.0	**2.14**	<1.00	<1.00	<1.00	<1.00	**24.1**	**6.27**	<5.00	**420**	<1.00	**2.29**	**1.88**	<1.00	<1.00	**16**	**275**
	02/27/13	<1.00	<1.00	<1.00	**14.6**	**4.17**	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	**5.47**	**2.18**	**39.4**	**96.6**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	**111**
	03/27/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**5.85**	<1.00	<1.00	<1.00	<1.00	<1.00	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	**6.71**	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	**1.77**	<1.00	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	**1.07**	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	10/03/13	<1.00	<1.00	<1.00	**3.22**	**1.4**	<50.0	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	**1.86**	<1.00	<5.00	**5.98**	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OR 5W	10/04/12	**1.05**	<1.00	<1.00	**52.5**	**25.6**	<50.0	<50.0	**3.11**	<1.00	<1.00	<1.00	<1.00	**19.5**	**6.83**	<5.00	**722**	<1.00	**2.76**	**3.54**	<1.00	**1.3**	**19.9**	**383**
	02/28/13	<1.00	<1.00	<1.00	**29.1**	**6.98**	<50.0	<50.0	**1.35**	<1.00	**1.01**	<1.00	<1.00	**3.76**	**2.76**	<5.00	**657**	**2.68**	**1.1**	**1.6**	<1.00	<1.00	<1.00	**133**
	03/27/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	<50.0	**1.81**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<5.00	**6.68**	<1.00	<1.00	<1.00	<1.00	**1.5**	<3.00	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**155**	<1.00	**3.79**	**1.85**	<1.00	**14.3**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**91.5**	<1.00	<1.00	**1.92**	<1.00	**11.4**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	10/03/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**143**	<1.00	<1.00	**1.63**	<1.00	**7.59**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
OR 10S	10/04/12	**1.05**	<1.00	<1.00	**71.8**	**27.3**	<50.0	<50.0	**24.3**	<1.00	**1.13**	<1.00	<1.00	**46.8**	**10.7**	<5.00	**1,040**	<1.00	**4.62**	**3.25**	<1.00	**4.5**	**62.1**	**619**
	02/28/13	<1.00	<1.00	<1.00	**10.5**	<1.00	<50.0	**210**	**20.6**	**1.89**	**27.7**	<1.00	**4.76**	**56.8**	**9.98**	<5.00	**1,580**	<1.00	**3.33**	**1.06**	<1.00	**3.45**	**29.2**	<500
	03/27/13	<1.00	<1.00	<1.00	**36.5**	**7.02**	<50.0	**174**	**12.8**	**1.3**	**16.4**	<1.00	**4.19**	**42.5**	**7.34**	<5.00	**1,480**	<1.00	**2.38**	**1.26**	<1.00	**2.43**	**44**	<500
	07/30/13	<1.00	<1.00	<1.00	**18.2**	**2.33**	<50.0	**202**	**5.51**	**4.1**	**17.5**	<1.00	**6.64**	**11.5**	**4.12**	<5.00	**1,780**	<1.00	**1.57**	<1.00	<1.00	<1.00	**11.1**	**194**
	09/12/13	<1.00	<1.00	<1.00	**25.5**	**4.8**	<50.0	**132**	**5.74**	<1.00	**15.1**	<1.00	**6.06**	**10.3**	**3.58**	<5.00	**1,640**	<1.00	**1.26**	<1.00	<1.00	<1.00	**13.2**	**201**
	10/03/13	<1.00	<1.00	<1.00	**18.4**	**4.51**	<50.0	**194**	**10.1**	<1.00	**9.69**	<1.00	**5.46**	**12.5**	**3**	<5.00	**938**	<1.00	<1.00	<1.00	<1.00	**1.07**	**16.3**	**264**

Table 17. Results for Volatile Organic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone (MEK)	Acetone	Benzene	Bromomethane	Carbon Disulfide	Chloroform	Chloromethane	Ethylbenzene	Isopropylbenzene	Methylene chloride	Naphthalene	n-Butylbenzene	n-Propylbenzene	p-Isopropyltoluene	Styrene	Toluene	Xylenes, total	Gasoline Range Organics
	RBSL	--	--	--	--	--	--	--	5	--	--	--	--	700	--	--	25	--	--	--	--	1,000	10,000	--
OR 10W	10/04/12	<1.00	<1.00	<1.00	**120**	**38.6**	<50.0	<50.0	**8.27**	<1.00	<1.00	<1.00	<1.00	**59.9**	**15**	<5.00	**944**	<1.00	**6.76**	<1.00	<1.00	<1.00	**42.3**	**723**
	02/28/13	<1.00	<1.00	<1.00	**1.32**	<1.00	<50.0	**50.8**	**1.32**	**2.79**	**8.36**	<1.00	**3.99**	<1.00	<1.00	**14.6**	**189**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<100
	03/27/13	<1.00	<1.00	<1.00	**1.36**	<1.00	<50.0	**59.8**	**4.32**	**5.16**	**10.1**	<1.00	**9.43**	<1.00	<1.00	<5.00	**167**	<1.00	<1.00	<1.00	<1.00	**3.06**	**3.11**	<100
	07/30/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**75**	<1.00	**1.36**	**1.67**	<1.00	**9.00**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100
	09/12/13	<1.00	<1.00	<1.00	<1.00	<1.00	<50.0	**41.9**	<1.00	<1.00	**1.68**	<1.00	**4.86**	<1.00	<1.00	<5.00	<5.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<100

Notes: Units are in micrograms per liter (µg/L).
Detections are in bold. Gray shaded are concentration exceeds Risk Based Screening Level (RBSL)

-- = RBSL not established for this compound
< = less than the reported detection limit
ISCO = in-situ chemical oxidation
PWR = partially weathered rock

Table 18. Results for Semivolatile Organic Compounds – PWR Performance Monitoring

Monitoring Well	Date Sampled	1-Methyl naphthalene	2-Methyl naphthalene	4-Chloroaniline	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Dibenzo(a,h)anthracene	Dibenzofuran	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Phenol	Pyrene	Diesel Range Organics
	RBSL (µg/L)	25*	25*	--	--	--	--	10	--	10	--	10	--	--	10	10	--	--	--	--	25*	--	--	--	--
MW 13S	10/03/12	**458**	**27.1**	<10	**184**	**13.1**	**17.3**	**6.47**	**5.01**	**4.9**	**2.3**	<2	<10	**26**	**4.86**	<2	**21.5**	**18.1**	**44.9**	<2	**32.3**	**75.9**	**10.9**	**21.2**	**131,000**
	02/27/13	**3,690**	**1,370**	<21.3	**1,210**	**228**	**437**	**204**	**173**	**174**	**71.2**	**79.3**	<21.3	**39.7**	**146**	**14.2**	**273**	**541**	**633**	**63**	**3,040**	**2,220**	<21.3	**730**	**121,000**
	03/28/13	NA	NA	NA	**879**	**79**	**346**	**176**	**81.6**	**80.5**	**45.3**	**38.7**	NA	NA	**87.7**	**8.84**	NA	**424**	**514**	**37.6**	**1,370**	**1,400**	NA	**496**	**109,000**
	07/30/13	**258**	**238**	<11.1	**35.9**	**41.3**	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	**22.6**	<2.22	<2.22	**12.5**	<2.22	<2.22	<2.22	**866**	**4**	<11.1	<2.22	**5,590**
MW 13D	10/03/12	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	<10.2	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	10.2	<2.04	**1,410**
	02/27/13	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<2.22	**111**
	07/30/13	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<2.22	<95.2
MW 13 ISOC	10/03/12	**552**	**12.3**	<11.8	**69.4**	**55**	**4.49**	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	**28.3**	<2.35	<2.35	**17.4**	<2.35	**28.1**	<2.35	**570**	**30.9**	<11.8	<2.35	**4,530**
	02/27/13	**152**	**102**	<10.9	**4.72**	**6.46**	<2.17	<2.17	<2.17	<2.17	<2.17	<2.17	<10.9	<10.9	<2.17	<2.17	<10.9	<2.17	<2.17	<2.17	**1,220**	<2.17	<10.9	<2.17	**5,490**
	03/27/13	NA	NA	NA	**12.4**	**10.4**	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	**4.38**	<1.9	<1.9	<1.9	NA	<1.9	**6,600**
	07/31/13	**253**	**11.6**	<10.0	**65.6**	**5.63**	**4.97**	<2.0	<2.0	<2.0	<2.0	<2.0	**15.1**	<10.0	<2.0	<2.0	**11.4**	**3.04**	**24.5**	<2.0	**218**	**24.6**	<10.0	**3.41**	**3,020**
	09/12/13	**8.15**	<2.15	<10.8	<2.15	**4.63**	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	<10.8	<2.15	<2.15	<10.8	<2.15	<2.15	<2.15	<2.15	<2.15	<10.8	<2.15	**1,190**
	10/03/13	NA	NA	NA	**3.79**	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NA	NA	<2.35	<2.35	NA	<2.35	<2.35	<2.35	**17.9**	<2.35	NA	<2.35	**975**
OS 5S	10/05/12	**605**	**501**	<12.5	**134**	**6.01**	**7.51**	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	**47.4**	<2.5	<2.5	**20.4**	**2.55**	**38.1**	<2.5	**2,090**	**40.6**	<12.5	**3.19**	**6,220**
	02/28/13	**83.7**	**76.4**	<10.4	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<10.4	<10.4	<2.08	<2.08	**11.6**	<2.08	**10.5**	<2.08	**195**	**19.4**	<10.4	<2.08	**2,490**
	03/28/13	NA	NA	NA	**2.95**	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	**7.09**	<1.9	**73.4**	**15**	NA	<1.9	**1,760**
	07/30/13	**17.1**	**15.2**	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	**2.44**	<2.22	**13.6**	**6.15**	<11.1	<2.22	**304**
	09/12/13	**50.5**	**42.1**	<11.1	**5.75**	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	**2.41**	**5.88**	<2.22	**100**	**14.3**	<11.1	<2.22	**1,060**
OS 5E	10/05/12	**84.9**	**50.8**	<12.5	**26.6**	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	<2.5	**9.53**	<2.5	**85.1**	**10.3**	<12.5	<2.5	**872**
	02/28/13	**17.8**	**2.75**	<10.5	**2.81**	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<10.5	<10.5	<2.11	<2.11	<10.5	<2.11	<2.11	<2.11	**29.1**	**2.92**	<10.5	<2.11	**460**
	03/28/13	NA	NA	NA	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	<1.9	<1.9	<1.9	<1.9	NA	<1.9	**150**
	07/30/13	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<2.22	<111
	09/12/13	<2.38	<2.38	<11.9	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	<11.9	<11.9	<2.38	<2.38	<11.9	<2.38	<2.38	<2.38	<2.38	<2.38	<11.9	<2.38	<125

Table 18. Results for Semivolatile Organic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1-Methyl naphthalene	2-Methyl naphthalene	4-Chloroaniline	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Dibenzo(a,h)anthracene	Dibenzofuran	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Phenol	Pyrene	Diesel Range Organics
	RBSL (µg/L)	25*	25*	--	--	--	--	10	--	10	--	10	--	--	10	10	--	--	--	--	25*	--	--	--	--
OS 10S	10/05/12	526	524	<12.5	132	4.31	8.64	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	28.5	<2.5	<2.5	19.5	2.5	41.1	<2.5	1,150	45.6	<12.5	2.99	5,460
	02/28/13	190	177	<10.5	44.5	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<10.5	<10.5	<2.11	<2.11	<10.5	<2.11	17.4	<2.11	231	28.7	<10.5	<2.11	2,460
	03/27/13	NA	NA	NA	23.2	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	2.36	10.7	<1.9	75.1	20.1	NA	<1.9	1,620
	07/30/13	160	134	<11.1	41.7	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	47.1 B	<11.1	<2.22	<2.22	<11.1	2.35	17.3	<2.22	187	26.6	<11.1	<2.22	1,170
	09/12/13	38.8	29.2	<11.1	2.53	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	6.24	<2.22	25	12.9	<11.1	<2.22	1,570
	10/03/13	NA	NA	NA	4.32	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NA	NA	<2.22	<2.22	NA	<2.22	3.1	<2.22	3	6.19	NA	<2.22	598
OS 10E	10/05/12	142	67.2	37.8	56.9	<2.5	6.9	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	2.66	24	<2.5	111	35.3	<12.5	3.45	1,310
	02/28/13	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	<10.2	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	2.57	<2.04	<10.2	<2.04	152
	03/28/13	NA	NA	NA	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	<1.9	<1.9	<1.9	<1.9	NA	<1.9	465
	07/30/13	<2.67	<2.67	<13.3	<2.67	<2.67	<2.67	<2.67	<2.67	<2.67	<2.67	<2.67	<13.3	<13.3	<2.67	<2.67	<13.3	<2.67	<2.67	<2.67	<2.67	<2.67	<13.3	<2.67	<125
	09/12/13	188	18.5	<10.0	37.20	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<10.0	13.2	<2.00	<2.00	<10.0	<2.00	9.83	<2.00	313	6.91	<10.0	<2.00	1,520
	10/03/13	NA	NA	NA	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NA	NA	<2.35	<2.35	NA	<2.35	<2.35	<2.35	<2.35	<2.35	NA	<2.35	152
OS 15S	10/05/12	424	226	<10.2	141	4.69	9.16	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	11.5	<2.04	<2.04	15.2	4.25	39	<2.04	349	45.6	<10.2	4.98	3,940
	02/28/13	5.23	<2.04	<10.2	10.7	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	113	<10.2	<2.04	<2.04	<10.2	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	2.65	566
	03/27/13	NA	NA	NA	8.54	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	1.92	709
	07/30/13	4.32	<2.22	<11.1	3.07	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	125 B	<11.1	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<2.22	116
	09/12/13	31.4	4.38	<11.1	15	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	6.21	<2.22	11.3	4.06	<11.1	<2.22	834
	10/03/13	NA	NA	NA	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NA	NA	<2.22	<2.22	NA	<2.22	<2.22	<2.22	<2.22	<2.22	NA	<2.22	668
OS 20S	10/05/12	744	607	<11.8	187	8.01	8.86	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	53.8	<2.35	<2.35	29	2.53	51.8	<2.35	1,660	50.4	<11.8	3.55	6,290
	02/28/13	340	200	<10.3	59.1	<2.06	2.73	<2.06	<2.06	<2.06	<2.06	<2.06	<10.3	<10.3	<2.06	<2.06	14	2.27	21.1	<2.06	653	27.8	<10.3	3.46	3,820
	03/27/13	NA	NA	NA	45.1	3.02	3.58	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	3.34	17.5	<1.9	12.2	11.1	NA	3.53	3,120
	07/30/13	46	11.7	<12.5	15.3	2.58	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	<2.5	2.84	<2.5	136	8.64	<12.5	<2.5	782
	09/12/13	216	71.4	<10.6	38.9	9.57	2.29	<2.13	<2.13	<2.13	<2.13	<2.13	24.9	<10.6	<2.13	<2.13	<10.6	<2.13	11.2	<2.13	45	8.47	<10.6	2.39	5,660
OS 25S	10/05/12	573	78.1	<13.3	164	14.1	9.3	<2.67	<2.67	<2.67	<2.67	<2.67	<13.3	38.5	<2.67	<2.67	35.6	<2.67	53	<2.67	544	54.7	<13.3	3.31	4,720
	02/28/13	424	59.3	<10.0	91.1	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<10.0	15.4	<2.00	<2.00	29.6	<2.00	39.3	<2.00	409	39.7	<10.0	2.02	276
	07/31/13	417	36.6	<13.3	108	18	7.51	<2.67	<2.67	<2.67	<2.67	<2.67	<13.3	19.6	<2.67	<2.67	30.7	<2.67	44.3	<2.67	377	49.1	<13.3	2.02	4,220
	09/12/13	265	7.17	<12.5	102	11.6	6.23	<2.50	<2.50	<2.50	<2.50	<2.50	<12.5	19.5	<2.50	<2.50	22.2	<2.50	38.4	<2.50	<2.50	18.1	<12.5	2.63	4,590

Table 18. Results for Semivolatile Organic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1-Methyl naphthalene	2-Methyl naphthalene	4-Chloroaniline	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Dibenzo(a,h)anthracene	Dibenzofuran	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Phenol	Pyrene	Diesel Range Organics
	RBSL (µg/L)	25*	25*	--	--	--	--	10	--	10	--	10	--	--	10	10	--	--	--	--	25*	--	--	--	--
OR 3S	10/04/12	**616**	**191**	<10.2	**153**	**5.46**	**5.57**	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	**18.8**	<2.04	<2.04	**16**	<2.04	**32.8**	<2.04	**1,310**	**30.7**	<10.2	<2.04	**4,990**
	02/27/13	**46.7**	**14.9**	<10.2	**24.6**	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	<10.2	<2.04	<2.04	<10.2	**2.30**	**14**	<2.04	**32**	**38.8**	<10.2	<2.04	**1,950**
	03/27/13	NA	NA	NA	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	**3.51**	<1.9	**36.2**	**17.4**	NA	<1.9	**854**
	07/30/13	<2.11	<2.11	<10.5	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	**103 B**	<10.5	<2.11	<2.11	<10.5	<2.11	<2.11	<2.11	<2.11	<2.11	<10.5	<2.11	**598**
	09/12/13	<2.13	<2.13	<10.6	**2.52**	<2.13	<2.13	<2.13	<2.13	<2.13	<2.13	<2.13	<10.6	<10.6	<2.13	<2.13	<10.6	**2.41**	<2.13	<2.13	<2.13	<2.13	<10.6	<2.13	**857**
	10/03/13	NA	NA	NA	<2.17	<2.17	<2.17	<2.17	<2.17	<2.17	<2.17	<2.17	NA	NA	<2.17	<2.17	NA	<2.17	<2.17	<2.17	<2.17	<2.17	NA	<2.17	**345**
OR 3W	10/04/12	**346**	**45.6**	<10.2	**78.6**	**5.76**	**6.63**	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	<10.2	<2.04	<2.04	**11.7**	**2.64**	**26.5**	<2.04	**474**	**33.3**	<10.2	**2.7**	**4,810**
	02/28/13	**242**	**55.5**	<10.0	**62.2**	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<10.0	<10.0	<2.00	<2.00	**12.9**	**2.21**	**22**	<2.00	**386**	**33.7**	<10.0	<2.00	**2,810**
	03/27/13	NA	NA	NA	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	**14**	<1.9	**47.8**	**15.8**	NA	<1.9	**2,380**
	07/30/13	**26.7**	**4.92**	<11.1	**2.73**	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	**8.39**	<2.22	**6.39**	**14.4**	<11.1	<2.22	**657**
	09/12/13	**6.12**	<2.35	<11.8	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	<11.8	<2.35	<2.35	<11.8	<2.35	**2.76**	<2.35	<2.35	**4.27**	<11.8	<2.35	**1,000**
	10/03/13	NA	NA	NA	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NA	NA	<2.22	<2.22	NA	<2.22	**12.6**	<2.22	**37.4**	**18.4**	NA	<2.22	**1,580**
OR 5S	10/04/12	**78.7**	**31.6**	<10.2	**31.1**	**2.07**	**2.32**	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	<10.2	<2.04	<2.04	<10.2	<2.04	**11.1**	<2.04	**248**	**11.8**	<10.2	<2.04	**2,730**
	02/27/13	**37.3**	**3.52**	<10.4	**11.3**	**2.45**	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<10.4	<10.4	<2.08	<2.08	<10.4	<2.08	**3.23**	<2.08	**40.8**	**7.3**	<10.4	**2.21**	**840**
	03/27/13	NA	NA	NA	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	<1.9	<1.9	<1.9	<1.9	NA	<1.9	**592**
	07/30/13	<2.27	<2.27	<11.4	<2.27	<2.27	<2.27	<2.27	<2.27	<2.27	<2.27	<2.27	**659 B**	<11.4	<2.27	<2.27	<11.4	<2.27	<2.27	<2.27	<2.27	<2.27	<11.4	<2.27	**423**
	09/12/13	**44.9**	<2.5	<12.5	**14.4**	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<12.5	<12.5	<2.5	<2.5	<12.5	<2.5	**2.97**	<2.5	**7.53**	**2.78**	<12.5	<2.5	**343**
	10/03/13	NA	NA	NA	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NA	NA	<2.11	<2.11	NA	<2.11	<2.11	<2.11	<2.11	<2.11	NA	<2.11	**630**
OR 5W	10/04/12	**515**	**54.8**	<10.3	**90.1**	**6.81**	**6**	<2.06	<2.06	<2.06	<2.06	<2.06	<10.3	<10.3	<2.06	<2.06	**14.6**	<2.06	**30.5**	<2.06	**680**	**34.4**	<10.3	<2.06	**3,520**
	02/28/13	**462**	**62.6**	<10.4	**87.6**	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<10.4	<10.4	<2.08	<2.08	**15.5**	**2.16**	**26.6**	<2.08	**619**	**32.8**	<10.4	<2.08	**3,270**
	03/27/13	NA	NA	NA	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	<1.9	<1.9	<1.9	<1.9	NA	<1.9	**779**
	07/30/13	**39.7**	**5.46**	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	**5.39**	<2.22	**10.5**	**14.7**	<11.1	<2.22	**806**
	09/12/13	<2.38	<2.38	<11.9	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	<11.9	<11.9	<2.38	<2.38	<11.9	<2.38	<2.38	<2.38	<2.38	<2.38	<11.9	<2.38	**397**
	10/03/13	NA	NA	NA	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NA	NA	<2.35	<2.35	NA	<2.35	<2.35	<2.35	<2.35	<2.35	NA	<2.35	**448**
OR-10S	10/04/12	**371**	**299**	<10.2	**59.1**	**7.23**	**4.13**	<2.04	<2.04	<2.04	<2.04	<2.04	<10.2	**15.9**	<2.04	<2.04	<10.2	<2.04	**19.2**	<2.04	**888**	**23.5**	<10.2	<2.04	**4,750**
	02/28/13	**371**	**491**	<10.0	**49.2**	**3.60**	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<10.0	<10.0	<2.0	<2.0	**10.2**	<10.0	**14.9**	<2.0	**1,690**	**13.7**	<10.0	<2.0	**4,860**
	03/27/13	NA	NA	NA	**28.5**	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	**10.1**	<1.9	**886**	**10.4**	NA	<1.9	**5,810**
	07/30/13	**342**	**430**	<11.1	**34.9**	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	**17.5 B**	<11.1	<2.22	<2.22	<11.1	<2.22	**14.6**	<2.22	**1,550**	**14.5**	<11.1	<2.22	**4,310**
	09/12/13	**318**	**413**	<12.0	**50.2**	<2.41	<2.41	<2.41	<2.41	<2.41	<2.41	<2.41	**15.4**	**12.6**	<2.41	<2.41	<12.0	<2.41	**18.5**	<2.41	**1,130**	**18.9**	<12.0	<2.41	**6,670**
	10/03/13	NA	NA	NA	**15.3**	<2.41	<2.41	<2.41	<2.41	<2.41	<2.41	<2.41	NA	NA	<2.41	<2.41	NA	<2.41	**5.61**	<2.41	**311**	**5.17**	NA	<2.41	**4,650**

Table 18. Results for Semivolatile Organic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	1-Methyl naphthalene	2-Methyl naphthalene	4-Chloroaniline	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Dibenzo(a,h)anthracene	Dibenzofuran	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Phenol	Pyrene	Diesel Range Organics
	RBSL (µg/L)	25*	25*	--	--	--	--	10	--	10	--	10	--	--	10	10	--	--	--	--	25*	--	--	--	--
OR-10W	10/04/12	**438**	**82.8**	<10.0	**61.4**	**3.78**	**3.11**	<2.0	<2.0	<2.0	<2.0	<2.0	<10.0	**18.4**	<2.0	<2.0	<10.0	<2.0	**18.9**	<2.0	**1,040**	**15.2**	<10.0	<2.0	**3,680**
	02/28/13	**87.2**	**20.5**	<10.3	**7.9**	<2.06	<2.06	<2.06	<2.06	<2.06	<2.06	<2.06	<10.3	<10.3	<2.06	<2.06	<10.3	<2.06	**6.74**	<2.06	**146**	**13.3**	<10.3	<2.06	**1,060**
	03/27/13	NA	**NA**	NA	**4.01**	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	NA	NA	<1.9	<1.9	NA	<1.9	**4.05**	<1.9	**63**	**9.3**	NA	<1.9	**1,130**
	07/30/13	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<11.1	<2.22	<2.22	<11.1	<2.22	<2.22	<2.22	<2.22	<2.22	<11.1	<2.22	<118
	09/12/13	<2.35	<2.35	<11.8	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	**32.8**	<11.8	<2.35	<2.35	<11.8	<2.35	<2.35	<2.35	<2.35	<2.35	<11.8	<2.35	**122**

* RBSL includes the sum of methyl naphthalenes and napthalenes.

Notes: Units are in micrograms per liter (µg/L).
Detections are in bold. Gray shaded are concentration exceeds risk based screening level (RBSL)

B = compound was found in blank and sample
NA = not analyzed
ISCO = in-situ chemical oxidation
PWR = partially weathered rock

Table 19. Results for Inorganic Compounds – PWR Performance Monitoring

Monitoring Well	Date Sampled	Arsenic	Chromium	Lead	Selenium	Nitrate-Nitrogen	Sulfate	Alkalinity, Total ($CaCO_3$)
	RBSL (µg/L)	*0.05*	*0.1*	*0.015*	*0.05*	--	--	--
MW-13S	02/27/13	<0.05	0.225	<0.025	<0.05	NA	7,380	NA
	3/28/13 B	**0.616**	**3.1**	**0.065**	**0.125**	NA	19,900	NA
	3/28/13 A	0.0173	**0.0158**	0.0098	<0.01	NA	848	NA
	07/30/13	<0.01	<0.005	0.0066	<0.01	NA	528	NA
MW-13D	02/27/13	0.0110	<0.005	<0.005	<0.01	NA	4.74	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	17.4	NA
MW-13 ISOC	02/27/13	<0.05	<0.025	<0.025	<0.05	NA	5,630	NA
	03/27/13	<0.01	0.0155	<0.005	0.011	NA	4,260	NA
	07/31/13	<0.01	0.0065	<0.005	<0.01	NA	1,300	NA
	09/12/13	**0.208**	<0.005	**0.0359**	<0.01	NA	3,110	NA
OS 5N	02/28/13	<0.01	0.0605	<0.005	<0.01	NA	1,160	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	87	NA
	09/12/13	<0.01	<0.005	<0.005	<0.01	NA	75	NA
OS 5S	02/28/13	<0.01	**2.040**	<0.005	<0.01	NA	17,800	NA
	03/28/13	0.0258	**1.13**	<0.005	**0.0683**	NA	16,200	NA
	07/30/13	<0.01	0.082	<0.005	<0.01	NA	730	NA
	09/12/13	<0.01	0.0238	<0.005	<0.01	NA	2,090	NA
OS 5E	02/28/13	<0.01	0.097	**0.0233**	<0.01	NA	948	NA
	03/28/13	<0.01	0.0301	<0.005	<0.01	NA	237	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	51	NA
	09/12/13	<0.01	<0.005	<0.005	<0.01	NA	27.2	NA
OS 10S	02/28/13	0.0360	0.00830	**0.0293**	0.0178	NA	8,670	NA
	03/27/13	<1.0	<0.5	<0.50	<1.0	NA	2,660	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	579	NA
	09/12/13	<0.01	<0.005	<0.005	<0.01	NA	5,840	NA
OS 10E	02/28/13	<0.01	<0.005	0.0055	<0.01	NA	94.2	NA
	03/28/13	<0.01	<0.005	0.0115	<0.01	NA	125	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	17.2	NA
	09/12/13	<0.01	<0.005	<0.005	<0.01	NA	49.3	NA

Table 19. Results for Inorganic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	Arsenic	Chromium	Lead	Selenium	Nitrate-Nitrogen	Sulfate	Alkalinity, Total ($CaCO_3$)
	RBSL (µg/L)	*0.05*	*0.1*	*0.015*	*0.05*	--	--	--
OS 15S	02/28/13	<0.01	<0.005	<0.005	<0.01	NA	35.2	NA
	03/27/13	<0.01	<0.005	<0.005	<0.01	NA	122	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	159	NA
	09/12/13	**1.95**	<0.005	<0.005	<0.01	NA	14400	NA
OS 20S	02/28/13	0.0107	0.0152	<0.005	<0.01	NA	979	NA
	03/27/13	<0.01	<0.005	<0.005	<0.01	NA	432	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	57	NA
	09/12/13	<0.01	<0.005	<0.005	<0.01	NA	316	NA
OS 25S	02/28/13	<0.01	0.0190	<0.005	<0.01	NA	639	NA
	07/31/13	<0.01	<0.005	<0.005	<0.01	NA	24	NA
	09/12/13	<0.01	<0.005	<0.005	<0.01	NA	45.9	NA
OR 3S	02/27/13	<0.01	0.0426	<0.005	<0.01	NA	1,540	NA
	03/27/13	**0.162**	**1.10**	**0.0426**	0.0235	NA	11,400	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	1,290	NA
	09/12/13	<0.01	0.0239	<0.005	<0.01	NA	2,650	NA
OR-3W	02/28/13	<0.01	0.0666	<0.005	<0.01	NA	3,680	NA
	03/27/13	0.0141	**0.2390**	0.0139	0.0276	NA	6,170	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	12,800	NA
	09/12/13	<0.01	0.453	<0.005	<0.01	NA	15,100	NA
OR 5S	02/27/13	<0.01	<0.005	<0.005	<0.01	NA	47.7	NA
	03/27/13	<0.01	<0.005	<0.005	<0.01	NA	114	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	165	NA
	09/12/13	0.0106	**0.157**	<0.005	0.012	NA	485	NA
OR 5W	02/28/13	<0.01	<0.005	0.0051	<0.01	NA	2,790	NA
	03/27/13	0.0121	<0.005	<0.005	<0.01	NA	1,760	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	7,880	NA
	09/12/13	<0.01	**0.197**	<0.005	<0.01	NA	14,600	NA
OR 10S	02/28/13	<1.00	<0.500	<0.500	<1.00	NA	18,100	NA
	03/27/13	<0.10	**0.35**	<0.05	**0.103**	NA	18,700	NA
	07/30/13	<0.01	**0.121**	**0.055**	<0.01	NA	4,310	NA
	09/12/13	<0.01	<0.005	<0.005	<0.01	NA	20,000	NA

Table 19. Results for Inorganic Compounds – PWR Performance Monitoring (Continued)

Monitoring Well	Date Sampled	Arsenic	Chromium	Lead	Selenium	Nitrate-Nitrogen	Sulfate	Alkalinity, Total ($CaCO_3$)
	RBSL (µg/L)	*0.05*	*0.1*	*0.015*	*0.05*	--	--	--
OR 10W	02/28/13	<0.01	0.0937	0.0124	<0.01	NA	8,030	NA
	03/27/13	<0.01	0.0663	<0.005	0.0116	NA	5,350	NA
	07/30/13	<0.01	<0.005	<0.005	<0.01	NA	4,500	NA
	09/12/13	<0.01	0.0585	**0.0163**	0.0133	NA	7,540	NA

Notes: µg/L = micrograms per liter
$CaCO_3$ = calcium carbonate
ISCO = in-situ chemical oxidation
PWR = partially weathered rock
RBSL = Risk Based Screening Level

The lack of any significant change at wells OR 5S and OR 10S suggest that these observation wells may be screened in fractures that are not well connected to the injection point. As previously noted, significant changes were noted in geochemical parameters during the alkaline activated persulfate injection along the south line of shallow observation wells at OS 10S and OS 15S. These data suggest that the reduced influence at PWR wells OS 5S and OS 10S may have been caused by some oxidant short circuiting along fractures in the vicinity of these shallow observation wells.

Along the west line of injection wells (OR 3W to OR 10W), the final DO and ORP measurements during injections averaged 3.07 mg/L and -268 mV. During the March 27 sampling event, the DO measurements along the west axis wells averaged 5.7 mg/L, which was an increase relative to the levels observed during injection. However, ORP values along this axis of wells had increased from an average of -268 to 429 mV. These data suggest better distribution of the reagent along the western axis.

On April 9, 2013, 3 weeks post injection, the observation wells nearest the injection well, OR 3S and OR 3W, had measured persulfate concentrations of 14.50 mg/L in each of the wells suggesting uniform distribution and a radial area of influence. The wells located 5 feet from the injection point also saw increases in persulfate with concentrations of 8.5 g/L and 26 g/L in OR 5S and OR 5W, respectively. These data also infer better or more rapid distribution along the west axis.

Well OR 5S also saw a large increase in DO from 0.51 to 7.59 mg/L. Within the 10 foot radius of the injection point, DO increased from less than 1.0 mg/L to an average of 6.1 mg/L indicating an aerobic environment in this area. OR 10W also saw a significant increase in pH from 5.65 to 12.08 SU. ORP values along both the south and west axes averaged greater than 330 mV. The results from this event indicate the radius of influence is greater in the western direction from the injection well.

Persulfate concentrations were recorded at the highest levels in OR 3S, OR 3W, OR 5S, OR 10S, and OR 10W during the April 23, 2013 event. ORP values along both the south and west axes averaged greater than 260 mV. Additionally, ORP values in the shallow observation wells from OS 5S through OS 20S averaged 210 mV.

Sampling was also conducted on July 30, 2013 prior to starting the peroxide activated injections. Persulfate concentrations were not determined in any of the PWR wells since it was considered unlikely that any residual persulfate would be present four months after injection. DO remained elevated at the observation wells closest to the injection point. ORP values on both axes averaged greater than 350 mV.

During the first week of the peroxide activated injection, both DO, ORP, and specific conductance increased significantly at wells located 3 feet from the injection point and at MW-13 ISOC (Appendix I*)*. Less significant, but notable, changes in DO also occurred at observation wells OR 5W and OR 10W during the second and third week of those injections. DO levels and specific conductance did not increase significantly in wells OR 5S or OR 10S during that timeframe. Although an increase in ORP was evident at well OR 10S, ORP values fluctuated at OR 5S throughout the duration of the peroxide activated injections. Geochemical data collected on September 12, 2013 were consistent with the trend observed during the peroxide activated injections. DO levels were 8.95 mg/L at well OR 3S and averaged 5.4 mg/L along the western axis. ORP readings averaged 214 mV between wells OR 3S and OR 10S, but the ORP reading at OR 5S was 98 mV. The average ORP along the western axis was 419 mV. These data indicate that the preferred flow pathway was along the western axis and that short-circuiting occurred in the vicinity of well OR 5S. As previously noted, short circuiting in the vicinity of well OR 5S may be due to some fractures providing a preferential flow path to the overburden in this location.

At MW-13 ISOC, the ORP on September 12, 2013 was 152 mV. During the sodium hydroxide activated injections, elevated pH was noted at MW-13 ISOC. Additionally during the peroxide activated injections, significant changes in DO and specific conductance occurred during the first and second week of injection. These data indicate that the fracture(s) connecting MW-13 ISOC and the injection point are of larger aperture or less occluded than those intersecting the screened intervals of the other observation wells along the western axis.

8.3.3 Evaluation of Contaminant Treatment

Effectiveness of the amendment at treating the MGP contaminants was evaluated by the collection of the groundwater samples for laboratory analysis during four events (February 27, March 27, July 31, and September 12, 2013) prior to and following the injection. Benzene and naphthalene were the two primary COCs that were detected at concentrations above the RBSLs within the pilot area. Benzene and naphthalene concentrations by EPA Method 8260 exceeded their respective RBSLs at MW-13 ISOC, OR 3S, OR 10S, OR 3W, and OR 10W during the baseline sampling of September 2012. Only naphthalene concentrations exceeded the RBSL at OR 5S and OR 5W.

Sampling of the PWR observation wells following the overburden injection indicated that mineralization of MGP contaminants had occurred in the lower lithology as well as in the overburden. At observation wells OS 3S and OS 5S, benzene and BTEX concentrations had been reduced by more than 65%. Naphthalene concentrations at these two wells had been reduced by more than 75%. Additionally at wells OS 3S and OS 5S, TPH-GRO concentrations had declined by 93% and 60%, respectively, as a result of the overburden injections. Significantly less destruction of these contaminants was observed at observation well OS 10S.

Similar reductions in the concentrations of methyl naphthalenes, detected PAHs, and TPH-DRO occurred at PWR wells OS 3S and OS 5S from the overburden injections. As of February 28, 2013, concentrations of methyl naphthalenes had been reduced by more than 60%. At these wells, the concentrations of detected PAHs had also declined by 55% or more. TPH-DRO concentrations had also declined by 70% or more as a result of the overburden injections. As noted for the VOCs, less mineralization occurred at well OR 10S.

Similar mineralization of BTEX and naphthalene was observed at OR 3W and OR 5W. Concentrations of BTEX at these wells declined by more than 80%. The concentrations of naphthalene had declined by 99% at well OR 3W. Limited mineralization of naphthalene had occurred at wells OR 5W, but its concentration had been reduced by 80% at well OR 5W. TPH-GRO concentrations at these wells had declined by as much as 60% as a result of the overburden injections. Table 20 presents the baseline concentrations and extent of destruction of these contaminants as of February 27, 2013.

At two weeks after the hydroxide activated injection, some additional mineralization had occurred. Benzene concentrations were all below the respective RBSLs with the exception of OR 10S and MW-13 ISOC (Table 20). BTEX concentrations had further declined at all observation wells within 5 feet of the injection point. Significant additional mineralization of naphthalene was observed at wells OR 3S, OR 5S, and OR 5W, and naphthalene concentrations by EPA Method 8260 were all below the RBSL for the wells within 5 feet. Only limited additional destruction of BTEX and naphthalene occurred at the observation wells 10 feet from the injection point.

Significant additional mineralization of detected PAHs and TPH-DRO occurred at observation wells within 5 feet of the injection point as a result of the hydroxide activated injection. The sum of the detected PAHs declined from 79.7 to 20.9 μg/L at well OR 3S, and PAH concentrations were below detection limits at wells OR 5S and OR 5W. TPH-DRO concentrations also declined significantly from 1,950 to 654 μg/L at well OR 3S and from 3,270 to 779 μg/L at well OR 5W. Limited contaminant destruction was observed at well OR 10S and MW-13 ISOC.

Approximately three months post-injection benzene concentrations were all less than the 1.0 μg/L MDL with the exception of wells OR 10S and MW-13 ISOC (Table 20). These two wells decreased 77% and 82%, respectively, from the baseline values, but remain above the RBSL. The wells are at a farther distance from the injection point

Table 20. Summary of Treatment Effectiveness

Well	Date	Benzene	BTEX	Total Alkyl Benzenes	Naphthalene	TPH-GRO	Methyl Naphthalenes	Detected PAHs	TPH-DRO
	RBSL (µg/L)	5	--	--	25	--	25	--	--
OR 3S	10/4/12	**5.06**	77.3	199.7	**1,670**	**690**	**807**	262.4	4,990
	2/27/13	**1.69**	1.69	4.42	**78.9**	<100	**61.6**	29.7	1,950
	3/27/13	<1.00	U	U	**10.5**	<100	NA	20.9	654
	7/30/13	<1.00	U	U	U	<100	U	U	598
	10/3/13	<1.00	U	U	U	<100	U	U	345
Percent Reduction		*80%*	*99%*	*98%*	*99%*	*86%*	*92%*	*92%*	*93%*
OR 5S	10/4/12	**2.14**	42.2	52.5	**420**	**275**	**110.3**	58.4	2,730
	2/27/13	<1.00	5.47	18.7	**96.6**	**111**	**40.8**	26.5	840
	3/27/13	<1.00	U	U	**5.85**	<100	NA	U	592
	7/30/13	<1.00	U	U	<5.00	<100	U	U	423
	10/3/13	<1.00	1.86	4.6	**5.98**	<100	**44.9**	20.1	630
Percent Reduction		*53%*	*96%*	*91%*	*99%*	*64%*	*59%*	*66%*	*77%*
OR 10S	10/4/12	**24.3**	137.7	117.6	**1,040**	**619**	**670**	129.06	4,750
	2/28/13	**20.6**	110.1	15.8	**1,580**	<500	**862**	91.6	4,560
	3/27/13	**12.8**	101.7	43.5	**1,480**	<500	NA	49	5,810
	7/30/13	**5.51**	28.1	20.5	**1,780**	**194**	**772**	64	4,310
	10/3/13	**10.1**	40.0	22.9	**938**	**264**	**731**	26.07	4,650
Percent Reduction		*58%*	*71%*	*81%*	*10%*	*57%*	-	*80%*	*2%*
OR 3W	10/4/12	9.34	92.5	101.3	**532**	**509**	**390.6**	167.8	4,810
	2/28/13	1.54	5.29	29.8	**4.52**	**108**	**297.5**	133	2,810
	3/27/13	<1.00	U	U	<5.00	<100	NA	29.8	2,380
	7/30/13	<1.00	U	U	<5.00	<100	**31.6**	22.8	657
	10/03/13	<1.00	U	U	<5.00	<100	**6.12**	31.0	1,580
Percent Reduction		*89%*	*94%*	*71%*	*99%*	*80%*	*98%*	*82%*	*67%*
OR 5W	10/4/12	**3.11**	43.8	91.2	**722**	**383**	**569.8**	182.4	3,520
	2/28/13	**1.35**	5.11	44.2	**657**	**133**	**524.6**	164.7	3,270
	3/27/13	**1.81**	3.31	U	**6.68**	<100	NA	U	779
	7/30/13	<1.00	U	U	<5.00	<100	**45.1**	20.1	805
	10/3/13	<1.00	U	U	<5.00	<100	U	U	448
Percent Reduction		*68%*	*92%*	*52%*	*99%*	*74%*	*92%*	*89%*	*87%*

Table 20. Summary of Treatment Effectiveness (Continued)

Well	Date	Benzene	BTEX	Total Benzenes	Naphthalene	TPH-GRO	Methenol Naphthalene	Detected PAHs	TPH-DRO
	RBSL (μg/L)	5	--	--	25	--	25	--	--
OR 10W	10/4/12	**8.27**	110.47	180.4	**944**	**723**	**520.8**	120.8	3,680
	2/28/13	**1.32**	1.32	U	**189**	<100	**107.7**	27.9	1,060
	3/27/13	**4.32**	10.49	4.36	**167**	<100	NA	17.4	1,130
	7/30/13	<1.00	U	U	<5.00	<100	U	U	<100
	9/12/13	<1.00	U	U	<5.00	<100	U	U	122
Percent Reduction		*88%*	*91%*	*98%*	*99%*	*86%*	*79%*	*86%*	*97%*
MW-13 ISOC	10/3/12	**667**	1,265	153.7	**736**	**2,180**	**564.3**	233.6	4,530
	2/27/13	**495**	1,546	145.6	**1,430**	**4,700**	**254**	11.2	5,490
	3/27/13	**720**	2,102	183	**1,130**	**4,500**	NA	28.6	6,600
	7/31/13	**114**	209.6	44.3	**404**	**629**	**264.6**	143.1	3,020
	10/3/13	**13.6**	32.2	3.26	**70.6**	**108**	**9.2**	4.63	975
Percent Reduction		*98%*	*97%*	*98%*	*90%*	*95%*	*98%*	*98%*	*78%*

Notes: Detections are in bold.
Gray shaded are concentration exceeds Risk Based Screening Level (RBSL)

BTEX = benzene, toluene, ethylbenzene and total xylenes
DRO = diesel range organics
GRO = gasoline range organics
NA = not analyzed
TPH = total petroleum hydrocarbon
U = undetected

which increased the time required to see the results from the contact of oxidant with the contamination. Naphthalene concentrations by EPA Method 8260 remained below the 5.0 μg/L MDL in the wells within a 5-foot radius of the injection point and decreased to below the MDL in OR 10W. TPH-GRO concentrations were also below detection limits at all wells, except OR 10S and MW-13 ISOC.

The final round of sampling of the PWR observation wells was performed October 3, 2013. Benzene and BTEX were below detection limits at all wells, except OR 10S and MW-13 ISOC. Concentrations of BTEX had been reduced by 70% and 97% from baseline at OR 10S and MW-13 ISOC, respectively. Naphthalene concentrations also been reduced to below the MDL at all PWR observation wells, except OR 5S and OR 10S, and MW-13 ISOC. Significant additional mineralization of naphthalene had been achieved by the peroxide activated injection at both OR 10S and MW-13 ISOC. Naphthalene concentrations had declined from 404 to 70.6 μg/L at MW-13 ISOC and from 1,780 to 938 μg/L at well OR 10S as a result of the peroxide activated injection. TPH-GRO also declined significantly at MW-13 ISOC as a result of the final injection.

PAHs were below MDL at wells OR 3S, OR 5W, and OR 10W. A slight rebound in the concentrations of PAHs occurred at well OR 3S, but the sum of the PAHs at that well in the final sampling event was reduced approximately 70% from the baseline. TPH-DRO concentrations had been reduced by more than 65% from the baseline at all wells except OR 10S.

9.0 CONCLUSIONS

Pilot testing of ISCO involved injections into both the overburden and the PWR in the vicinity of MW-13S and MW-13 ISOC. In order to evaluate treatment effectiveness, observation wells were installed on both the primary flow axis and perpendicular to the primary axis in both lithologies.

The shallow zone ISCO pilot test consisted of injecting sodium persulfate solution activated by sodium hydroxide to mineralize dissolved BTEX, PAHs, and TPH. The stoichiometric demand for oxidant was determined from the estimated hydrocarbon mass derived from the data obtained during installation of the Pilot Study area injection wells. SOD was determined in the laboratory from soil samples from several borings installed at various locations at the Site in order to represent the various soil types known to be present. Based on the stoichiometry and SOD, the total oxidant demand for the shallow zone pilot test was estimated to be 17,760 lbs. The sodium persulfate was blended as a 20% solution for injection yielding an injection volume of 9,260 gallons. The activator demand was estimated at approximately 2,400 gallons of 25% sodium hydroxide.

In order to provide good distribution of the reagents in the aquifer and avoid issues related to surfacing of reagents or development of preferential pathways, the total volume of 12,360 gallons of reagents was injected in four separate events of approximately four days duration each. For each separate event, one fourth of the total reagent volume (approximately 3,000 gallons) was injected at a flow rate of approximately 2 gpm.

Monitoring to evaluate the performance of the ISCO injection consisted of two types: contaminant monitoring and geochemical monitoring. Performance monitoring for the shallow zone involving collection of samples for laboratory analyses of VOCs, SVOC, and TPH was conducted two, four, and seven weeks after injection. Geochemical monitoring consisted of measurement of field geochemical parameters (pH, ORP, DO, specific conductance, turbidity, and temperature) and collection of a grab sample for field analysis of persulfate. Geochemistry performance monitoring was performed prior to injection and approximately one, three, five, and six weeks after injection.

A final round of performance monitoring involving collection of samples for laboratory analyses from all shallow zone observation wells was conducted on September 12, 2013 after completion of the PWR injections. Wells OS 10E, OS 10S and OS 15S were also sampled on October 3, 2013 in conjunction with the final round of sampling of the PWR wells.

Figure 19 summarizes the performance monitoring results for VOCs in the shallow observation wells. During the performance monitoring event on February 28 that preceded the PWR injections, benzene concentrations were all less than the MDL with the exception of wells OS 20S and OS 25S. BTEX concentrations were at less than 10% of their baseline within 15 feet of the injection point. BTEX concentrations had been reduced by 74% and 25% at OS 20S and OS 25S, respectively.

As of February 28, 2013, TPH-GRO concentrations within 20 feet of the injection point had declined by 80% or more. At OS 25S, the TPH-GRO level had been reduced by 65% from its baseline.

In the February 28, 2013 performance monitoring event, naphthalene concentrations by EPA Method 8260 were decreased by at least 80% relative to baseline up to 15 feet downgradient. Naphthalene concentrations at OS 25S, which had been reduced by 50% in the previous sampling event, rebounded to baseline.

In the final performance sampling event, benzene concentrations were all less than the MDL with the exception of wells OS 20S and OS 25S. BTEX concentrations were at less than 10% of their baseline within 15 feet of the injection point. At wells OS 20S and OS 25S, BTEX concentrations had rebounded and were at levels above the initial baseline.

In the September performance event, naphthalene concentrations had been reduced by 95% relative to baseline at all shallow observation wells except well OS 20S. Naphthalene concentrations at OS 20S, which had been reduced by 73% in the previous sampling event, rebounded and were at 36% of the baseline.

TPH-GRO was also below its MDL at all wells within 15 feet of the injection point. TPH-GRO was at or very close to its baseline level in both OS 20S and OS 25S.

Performance monitoring results for the shallow zone injection for the PAHs and TPH-DRO are provided in Figure 20. During the February 28 sampling event, concentrations of methyl naphthalenes were reduced by 85% or more within 15 feet of the injection point except at well OS 10S. Routinely detected PAHs had also been reduced by 85% from their baseline at wells OS 5E, OS 10E, OS 5S, OS 10S, and OS 15S. At OS 10S and OS 20S, the levels of PAHs had declined by greater than 65% relative to baseline. TPH-DRO concentrations had declined by 45-60% at the observation wells within 10 feet of the injection point. At wells OS 15S and OS 25S, the concentration of TPH-DRO had been reduced by 85% from baseline and a 40% reduction from baseline had been achieved at OS 20S.

In the final performance sampling event, methyl naphthalenes and PAHs were reduced by 78% or more at all wells within 20 feet of the injection point except at well OS 10E. At well OS 10E, methyl naphthalenes were at their baseline concentration and PAHs were at 50% of their baseline. At well OS 25S, methyl naphthalenes and PAHs were at approximately 50% of their baseline concentrations.

TPH-DRO had been reduced by more than 80% from its baseline at all wells within 15 feet of the injection point. TPH-DRO was at or very close to its baseline level in both OS 20S and OS 25S.

The final monitoring event indicated some slight rebound in the concentrations of naphthalene and methyl naphthalenes at OS 10E. BTEX, naphthalenes, methyl naphthalenes, PAHs, and TPH had rebounded at 20 and 25 feet from the injection point. Some rebound in contaminant concentrations is common with ISCO due to increased desorption from soils or NAPLs as the contaminant levels in groundwater are reduced. For the shallow zone injection, the rebound appears limited to the edges of the anticipated treatment zone.

The initial pilot test injections in the PWR also involved introduction of alkaline activated persulfate. The initial dosing for the PWR pilot test was estimated at a total of approximately 3,800 lbs of sodium persulfate injected as a 20% solution (approximately 2,000 gallons) and approximately 500 gallons of 25% sodium hydroxide or 650 gallons of 20% sodium hydroxide solution. Due to the limited porosity of the PWR, the total volume of the reagents was planned to be injected in four separate events one week apart. The injection conditions for the PWR were a rate of approximately 0.5 to 1 gpm and 5 to 10 psi.

During the first week of injection in the PWR, the ORP went from very positive values to negative values on the second day of injection. By the end of the first week of injection, ORP values at most PWR wells were near -150 mV. Groundwater parameters taken during the second week of injection in the PWR indicated that ORP values had become very negative with values ranging from -40 to -370 mV. Similar geochemical results were obtained during the third week of injection in the PWR. Therefore, injections in the PWR were terminated to evaluate potential causes for the unexpected ORP readings.

In order to complete pilot testing in the PWR and evaluate hypothesized causes for the conditions observed during the alkaline activated injections in the PWR, the final injection in that lithology used hydrogen peroxide activated persulfate. Oxidant dosing for the remaining PWR pilot test injection utilized hydrogen peroxide as an activator and the remainder of the sodium persulfate that had not used in the previous three weeks of injection. The remaining sodium persulfate (1,925 lbs) was injected as approximately 1,010 gallons of 20% solution. Based on stoichiometric requirements and an estimated excess for native activator demand, approximately 2,640 gallons of 7% hydrogen peroxide was determined to be needed as activator.

Due to the limited porosity of the PWR, the total volume of the reagents was planned to be injected in three separate events that were implemented approximately one week apart. Each separate event involved injection of one third of the total reagent volume (approximately 1,220 gallons).

Figure 21 summarizes the performance monitoring results for VOCs in the PWR observation wells. Sampling of the PWR observation wells on February 28, 2013 (following the overburden injection) indicated that mineralization of MGP contaminants had occurred in the lower lithology as well as in the overburden. At observation wells OS 3S and OS 5S, benzene concentrations had been reduced by more than 65% and BTEX levels had been reduced by more than 80%. Benzene and BTEX levels had not been reduced at OR 10S or MW-13 ISOC. Along the western axis observation wells, benzene concentrations had also been reduced by more than 80% at wells OR 3W and OR 10W. At well OR 5W, benzene levels had been reduced 55% by the overburden injections. BTEX concentrations in all western axis wells had dropped by more than 85%.

Following the overburden injections, naphthalene concentrations at wells OR 3S, OR 5S, OR 3W, and OR 10W had been reduced by more than 75%. Concentrations of naphthalene had not been significantly affected at wells OR 5W, OR 10S, or MW-13 ISOC.

Figure 22 summarizes the performance monitoring results for PAHs and TPH-DRO at the PWR observation wells. As of February 28, 2013, concentrations of methyl naphthalenes had been reduced by more than 60% at wells OS 3S and OS 5S. At these wells, the concentrations of detected PAHs had also declined by 55% or more. TPH-DRO concentrations had also declined by 70% or more as a result of the overburden injections. As noted for the VOCs, less mineralization of PAHs and TPH-DRO occurred at well OR 10S and MW-13 ISOC.

Only limited destruction of methyl naphthalenes, PAHs, and TPH-DRO was observed at OR 3W and OR 5W as a result of the overburden injections. In general, the concentrations of these contaminants at these wells were reduced less than 40%.

Additionally, at wells OS 3S and OS 5S, TPH-GRO concentrations had declined by 93% and 60%, respectively, as a result of the overburden injections. Along the western axis wells, TPH-GRO was reduced by more than 65% as a result of the overburden injections.

Approximately three months post-injection benzene concentrations were all less than the 1.0 μg/L MDL with the exception of wells OR 10S and MW-13 ISOC. Benzene concentrations at these two wells decreased 77% and 82%, respectively, from the baseline values, but remain above the RBSL. Naphthalene concentrations by EPA

Method 8260 were below the 5.0 μg/L MDL in the wells within a 5 foot radius of the injection point and decreased to below the MDL in OR 10W. TPH-GRO concentrations were also below detection limits at all wells, but OR 10S and MW-13 ISOC.

PAHs had been reduced to below detection levels at wells OR 3S and OR 5S, but were still at 50% of baseline at OR 10S. TPH-DRO levels had also been reduced by more than 85% at wells OR 3S and OR 5S, but remained near baseline at OR 10S. Both PAHs and TPH-DRO concentrations had been reduced by more than 75% at all western axis wells except MW-13 ISOC. At MW-13 ISOC, PAHs and TPH-DRO had been reduced only 35% from baseline.

The final round of sampling of the PWR observation wells was performed October 3, 2013. Benzene and BTEX were below detection limits at all wells, but OR 10S and MW-13 ISOC. Concentrations of BTEX had been reduced by 70% and 97% from baseline at OR 10S and MW-13 ISOC, respectively. Naphthalene concentrations had also been reduced to below the MDL at all PWR observation wells, but OR 5S, OR 10S, and MW-13 ISOC. Significant additional mineralization of naphthalene had been achieved by the peroxide activated injection at both OR 10S and MW-13 ISOC. Naphthalene concentrations had declined from 404 to 70.6 μg/L at MW-13 ISOC and from 1,780 to 938 μg/L at well OR 10S as a result of the peroxide based injection. TPH-GRO also declined significantly at MW-13 ISOC as a result of the final injection. However, TPH-GRO had only been reduced by 60% from its baseline at well OR 10S.

PAHs were below MDL at wells OR 3S, OR 5W, and OR 10W. A slight rebound in the concentrations of PAHs occurred at well OR 5S, but the sum of the PAHs at that well in the final sampling event was reduced approximately 70% from the baseline. PAH concentrations were further reduced at well OR 10S and MW-13 ISOC to less than 20% of their baseline. TPH-DRO concentrations had been reduced by more than 65% from the baseline at all wells except OR 10S. At well OR 10S, TPH-DRO concentrations remained near baseline.

10.0 REFERENCES

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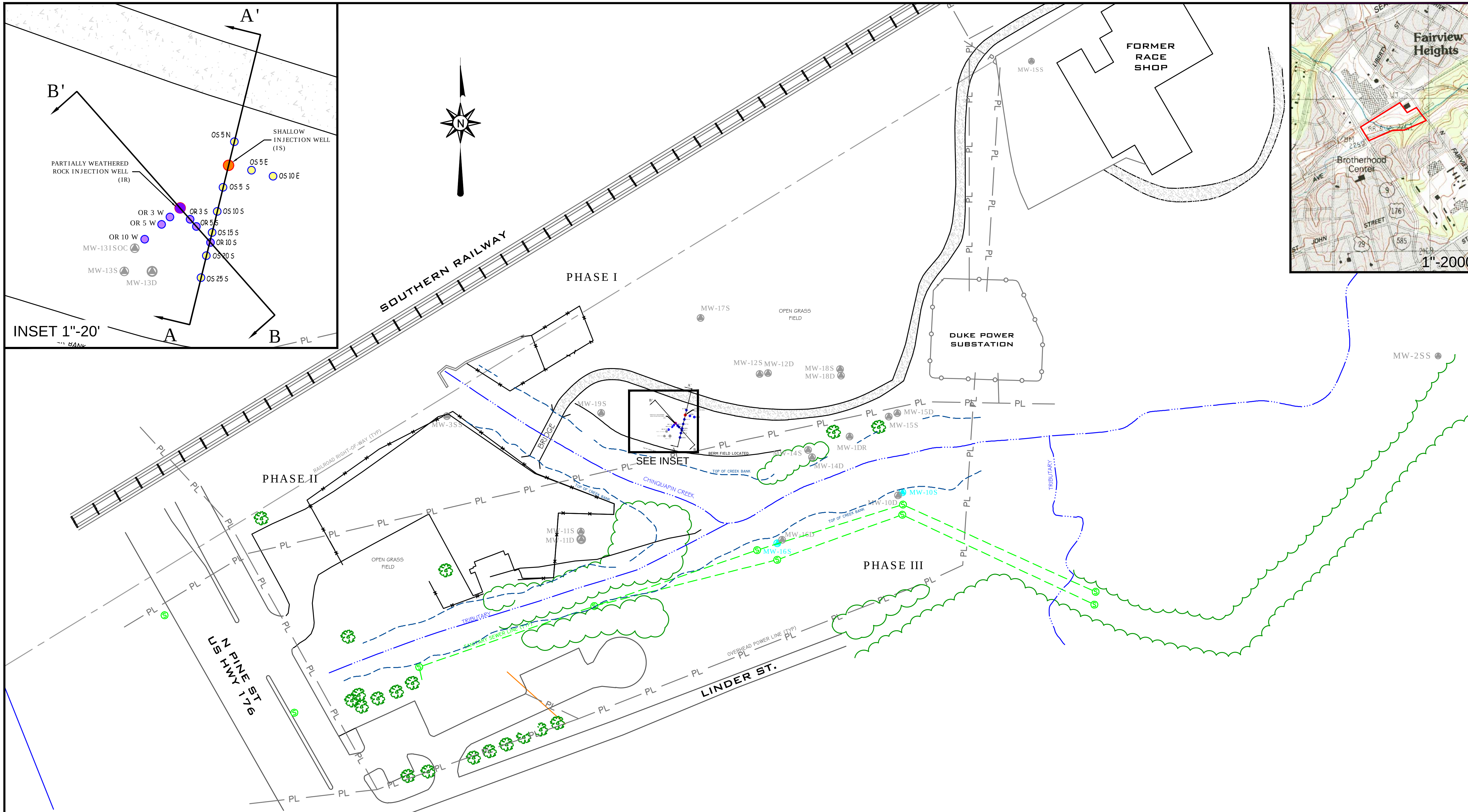
FIGURES



LEGEND

- SHALLOW WELL
- PARTIALLY WEATHERED ROCK MONITORING WELL
- SHALLOW INJECTION WELL
- PARTIALLY WEATHERED ROCK INJECTION WELL
- SANITARY SEWER MANHOLE
- PREVIOUS EXISTING MONITORING WELL LOCATION
- PROPERTY BOUNDARY LINE
- RAILROAD RIGHT-OF-WAY
- CREEK/TRIBUTARY
- FENCE
- PL — OVERHEAD POWER
- UNDERGROUND SANITARY SEWER

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

CLIENT: DUKE ENERGY

TITLE:
SITE VICINITY AND LAYOUT
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 100'		FIGURE NO.: FIGURE 1

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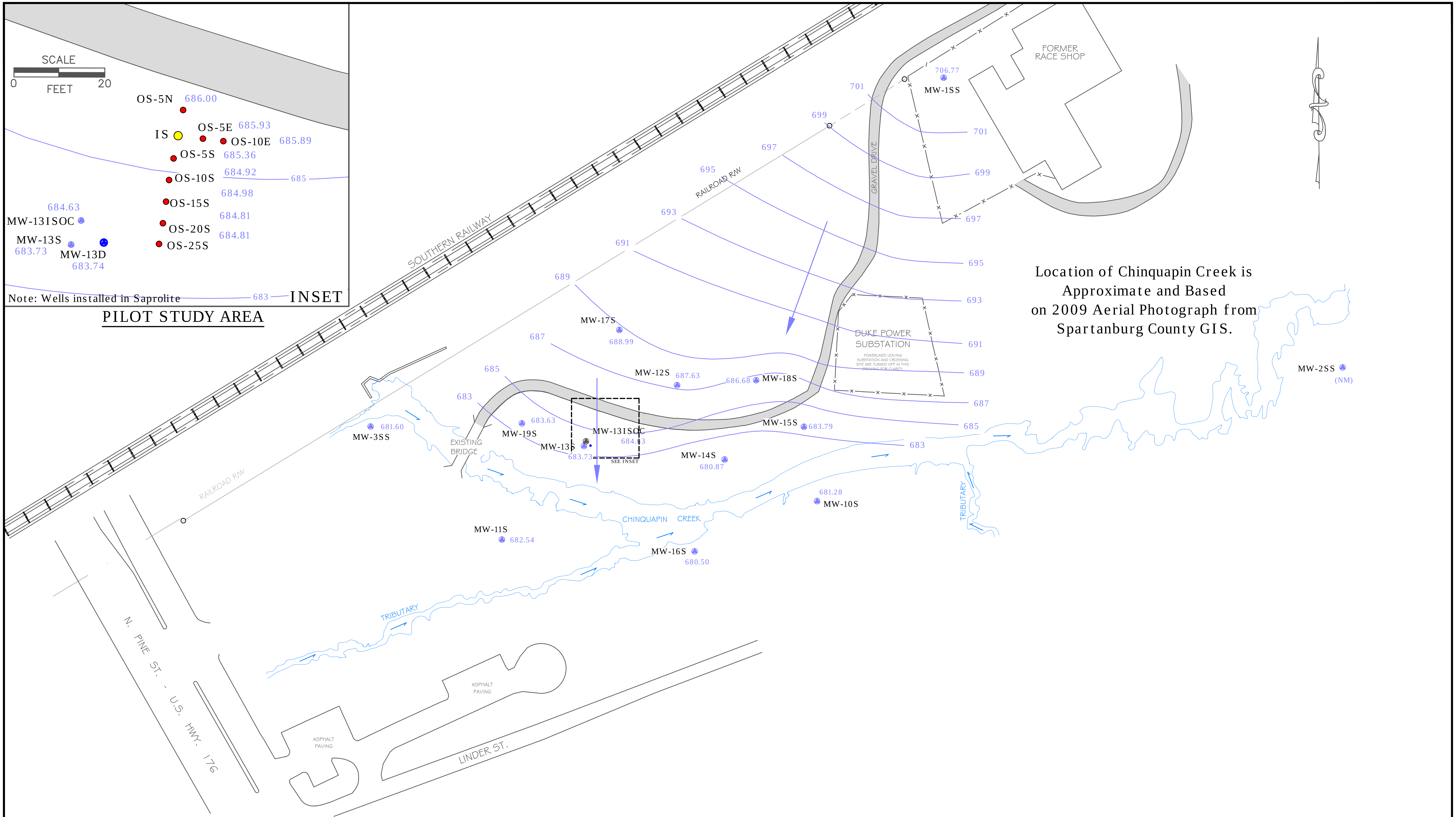

LEGEND

MW-10S	SAPROLITE GROUNDWATER WELL
OS-5E	OVERBURDEN OBSERVATION WELL
IS	OVERBURDEN INJECTION WELL
680.40	WATER LEVEL ELEVATION (feet msl)
	SAPROLITE GROUNDWATER CONTOUR
(NM)	NOT MEASURED
	GROUNDWATER FLOW DIRECTION
	SURFACE WATER FLOW DIRECTION

Wells South of Chinquapin Creek Were Not Contoured

AMEC Environment & Infrastructure
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

CLIENT: DUKE ENERGY

TITLE: GROUNDWATER ELEVATIONS IN SHALLOW WELLS - JULY/AUGUST 2013
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 100'		FIGURE. NO.: FIGURE 2

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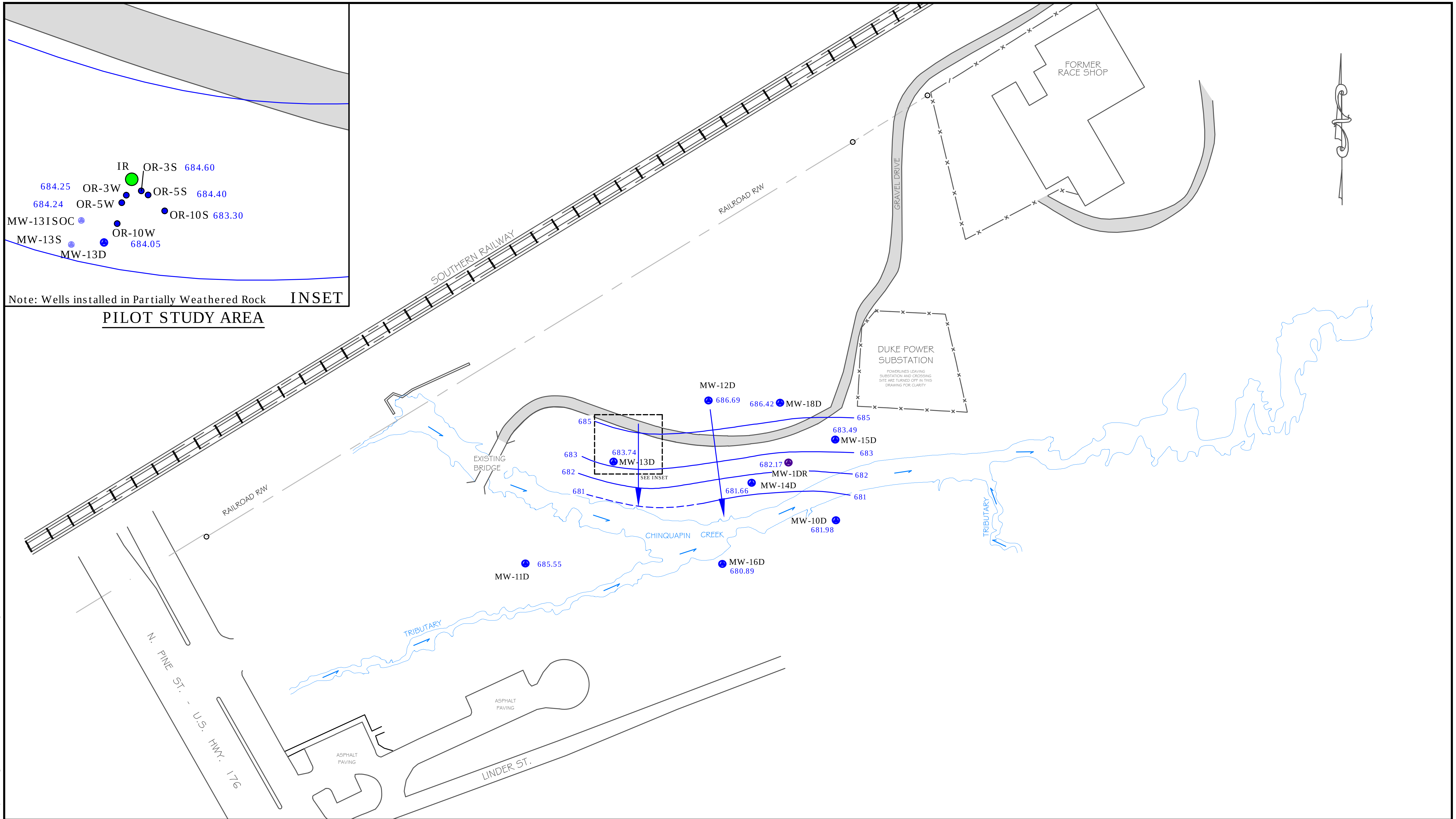


LEGEND

MW-11D	FRACTURED ROCK GROUNDWATER MONITORING WELL	681.39	WATER LEVEL ELEVATION (feet msl)
MW-1DR	DEEP BEDROCK GROUNDWATER MONITORING WELL		FRACTURED BEDROCK GROUNDWATER CONTOUR
OR-3W	PARTIALLY WEATHERED ROCK OBSERVATION WELL		GROUNDWATER FLOW DIRECTION
IR	PARTIALLY WEATHERED ROCK INJECTION WELL		SURFACE WATER FLOW DIRECTION

Wells South of Chinquapin Creek Were Not Contoured

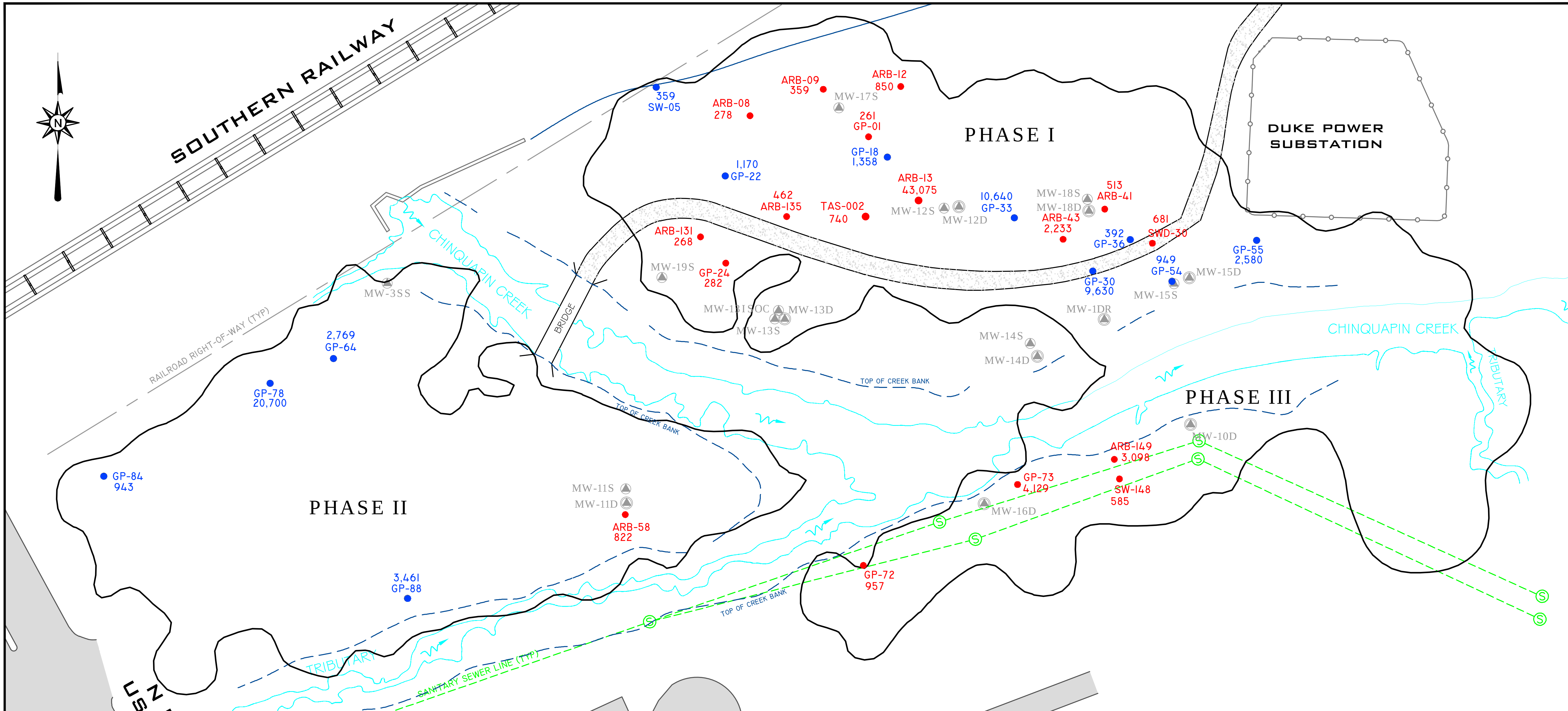
AMEC Environment & Infrastructure
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT:

TITLE:
GROUNDWATER ELEVATIONS IN BEDROCK AND FRACTURED ROCK WELLS - JULY/AUGUST 2013
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 100'		FIGURE. NO.: FIGURE 3

P:\CADD\Projects\6228120021 Duke Spartanburg SCIF 03 GW Elev in Bedrock Frac Rock.dwg Nov. 11, 2013 william.wiers



LEGEND:

MW-13S	OVERBURDEN GROUNDWATER MONITORING WELL
MW-13D	BEDROCK GROUNDWATER MONITORING WELL
MW-13ISOC	PARTIALLY WEATHERED ROCK GROUNDWATER MONITORING WELL
	APPROXIMATE LIMITS OF EXCAVATION REMEDIATION
GP-84	SAMPLE LOCATION, DESIGNATION, AND TPAH CONCENTRATION >250 mg/kg. REMEDIATION DOCUMENTATION SUGGESTS SAMPLE MAY LIKELY HAVE BEEN EXCAVATED DURING REMEDIATION, BUT IS NOT CONCLUSIVE.
ARB-58	SAMPLE LOCATION, DESIGNATION, AND TPAH CONCENTRATION >250 mg/kg. REMEDIATION DOCUMENTATION SUPPORTS THAT MEDIA WAS NOT EXCAVATED AND REMOVED DURING REMEDIATION, AND REMAINS IN-PLACE.

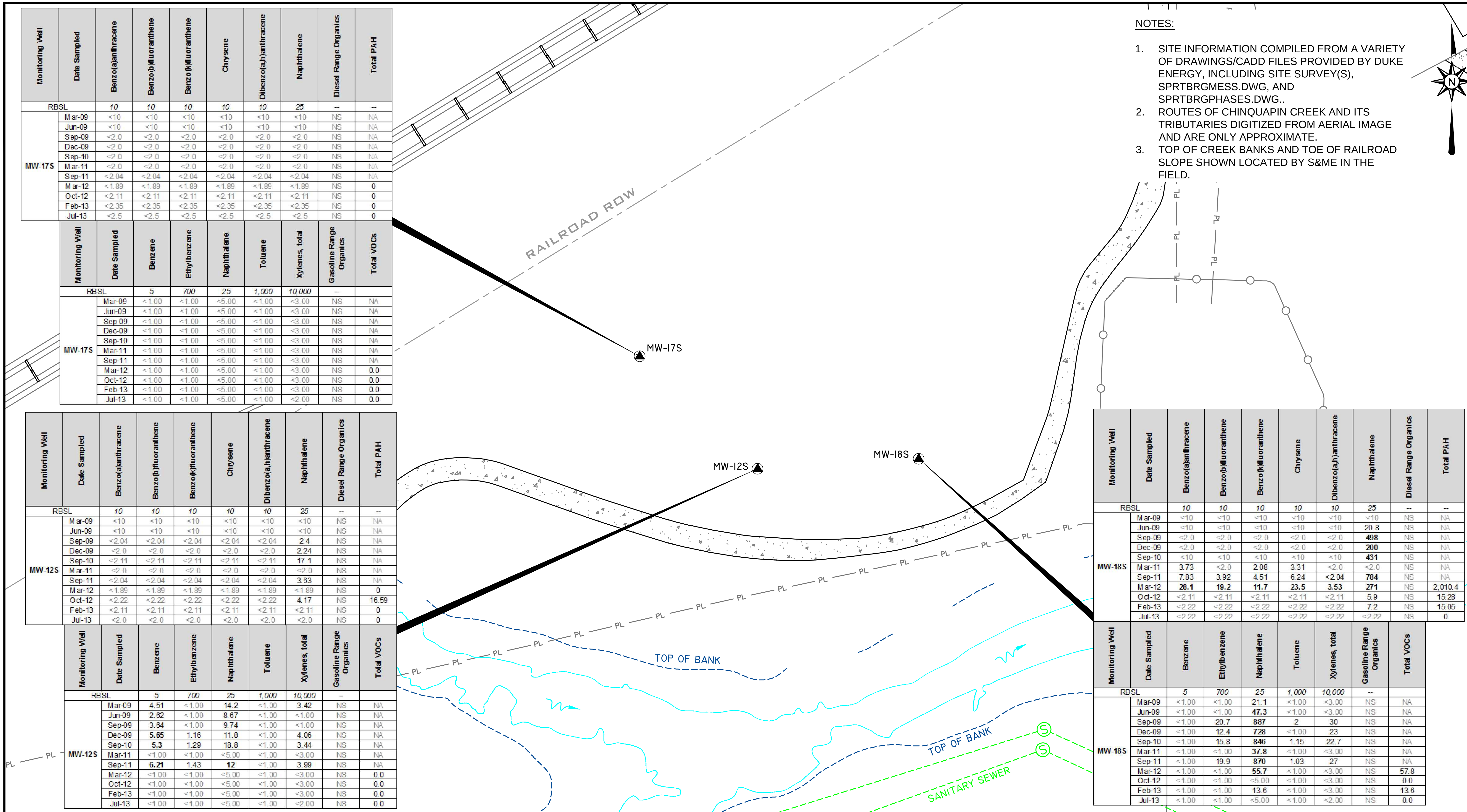
AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE: TOTAL TPAH > 250 mg/kg REMAINING AFTER EXCAVATION
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 60'		FIGURE NO.: FIGURE 4

P:\CADD\Projects\6228\622812\0021 Duke Spartanburg SCI\F 04 Total TPAH after Excav.dwg Nov. 11, 2013 william.wiers



Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		10	10	10	10	10	25	--	--
MW-17S	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	<10	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Feb-13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NS	0
	Jul-13	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-17S	Mar-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Dec-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		10	10	10	10	10	25	--	--
MW-12S	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	<10	NS	NA
	Sep-09	<2.04	<2.04	<2.04	<2.04	<2.04	2.4	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	2.24	NS	NA
	Sep-10	<2.11	<2.11	<2.11	<2.11	<2.11	17.1	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	3.63	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.22	<2.22	<2.22	<2.22	<2.22	4.17	NS	16.59
	Feb-13	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Jul-13	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-12S	Mar-09	4.51	<1.00	14.2	<1.00	3.42	NS	NA
	Jun-09	2.62	<1.00	8.67	<1.00	<1.00	NS	NA
	Sep-09	3.64	<1.00	9.74	<1.00	<1.00	NS	NA
	Dec-09	**5.65**	1.16	11.8	<1.00	4.06	NS	NA
	Sep-10	**5.3**	1.29	18.8	<1.00	3.44	NS	NA
	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	**6.21**	1.43	**12**	<1.00	3.99	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		10	10	10	10	10	25	--	--
MW-18S	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	20.8	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	**498**	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	**200**	NS	NA
	Sep-10	<10	<10	<10	<10	<10	**431**	NS	NA
	Mar-11	3.73	<2.0	2.08	3.31	<2.0	<2.0	NS	NA
	Sep-11	7.83	3.92	4.51	6.24	<2.04	**784**	NS	NA
	Mar-12	**28.1**	**19.2**	**11.7**	**23.5**	**3.53**	**271**	NS	2,010.4
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	5.9	NS	15.28
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	7.2	NS	15.05
	Jul-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-18S	Mar-09	<1.00	<1.00	21.1	<1.00	<3.00	NS	NA
	Jun-09	<1.00	<1.00	**47.3**	<1.00	<3.00	NS	NA
	Sep-09	<1.00	20.7	**887**	2	30	NS	NA
	Dec-09	<1.00	12.4	**728**	<1.00	23	NS	NA
	Sep-10	<1.00	15.8	**846**	1.15	22.7	NS	NA
	Mar-11	<1.00	<1.00	**37.8**	<1.00	<3.00	NS	NA
	Sep-11	<1.00	19.9	**870**	1.03	27	NS	NA
	Mar-12	<1.00	<1.00	**55.7**	<1.00	<3.00	NS	57.8
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	13.6	<1.00	<3.00	NS	13.6
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG..
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

LEGEND:

MW-13S — OVERBURDEN GROUNDWATER MONITORING WELL

— PL —— PL — POWER LINE

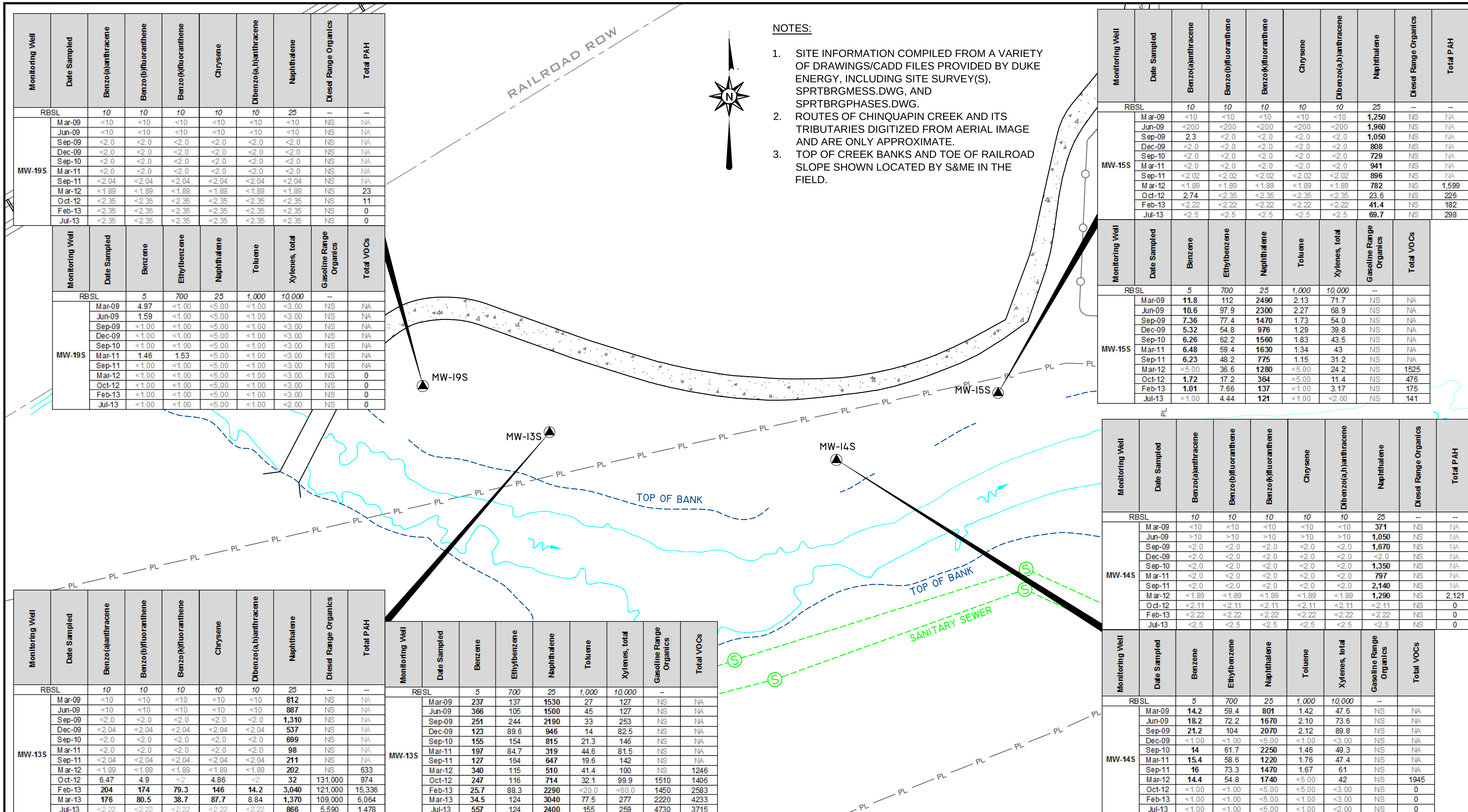
AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

CLIENT: DUKE ENERGY

TITLE: HISTORIC GROUNDWATER RESULTS
SHALLOW WELLS PHASE 1
AREA NORTH OF ROAD
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 50'		FIGURE. NO.: FIGURE 5



NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG.
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		10	10	10	10	10	25	--	--
MW-19S	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	<10	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	23
	Oct-12	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NS	11
	Feb-13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NS	0
	Jul-13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-19S	Mar-09	4.97	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	1.59	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Dec-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-11	1.46	1.53	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		10	10	10	10	10	25	--	--
MW-15S	Mar-09	<10	<10	<10	<10	<10	1,250	NS	NA
	Jun-09	<200	<200	<200	<200	<200	1,960	NS	NA
	Sep-09	2.3	<2.0	<2.0	<2.0	<2.0	1,050	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	808	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	729	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	941	NS	NA
	Sep-11	<2.02	<2.02	<2.02	<2.02	<2.02	896	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	782	NS	1,599
	Oct-12	2.74	<2.35	<2.35	<2.35	<2.35	23.6	NS	226
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	41.4	NS	182
	Jul-13	<2.5	<2.5	<2.5	<2.5	<2.5	69.7	NS	298

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-15S	Mar-09	11.8	112	2490	2.13	71.7	NS	NA
	Jun-09	10.6	97.9	2300	2.27	68.9	NS	NA
	Sep-09	7.36	77.4	1470	1.73	54.0	NS	NA
	Dec-09	5.32	54.8	976	1.29	39.8	NS	NA
	Sep-10	6.26	62.2	1560	1.83	43.5	NS	NA
	Mar-11	6.48	59.4	1630	1.34	43	NS	NA
	Sep-11	6.23	48.2	775	1.15	31.2	NS	NA
	Mar-12	<5.00	36.6	1280	<5.00	24.2	NS	1525
	Oct-12	1.72	17.2	364	<5.00	11.4	NS	476
	Feb-13	1.01	7.66	137	<1.00	3.17	NS	175
	Jul-13	<1.00	4.44	121	<1.00	<2.00	NS	141

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		10	10	10	10	10	25	--	--
MW-14S	Mar-09	<10	<10	<10	<10	<10	371	NS	NA
	Jun-09	>10	>10	>10	>10	>10	1,050	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	1,670	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	1,350	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	797	NS	NA
	Sep-11	<2.0	<2.0	<2.0	<2.0	<2.0	2,140	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	1,290	NS	2,121
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0
	Jul-13	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-14S	Mar-09	14.2	59.4	801	1.42	47.6	NS	NA
	Jun-09	18.2	72.2	1670	2.10	73.6	NS	NA
	Sep-09	21.2	104	2070	2.12	89.8	NS	NA
	Dec-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-10	14	61.7	2250	1.46	49.3	NS	NA
	Mar-11	15.4	58.6	1220	1.76	47.4	NS	NA
	Sep-11	16	73.3	1470	1.67	61	NS	NA
	Mar-12	14.4	54.8	1740	<5.00	42	NS	1945
	Oct-12	<1.00	<1.00	<5.00	<5.00	<3.00	NS	0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		10	10	10	10	10	25	--	--
MW-13S	Mar-09	<10	<10	<10	<10	<10	812	NS	NA
	Jun-09	<10	<10	<10	<10	<10	887	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	1,310	NS	NA
	Dec-09	<2.04	<2.04	<2.04	<2.04	<2.04	537	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	699	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	98	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	211	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	202	NS	633
	Oct-12	6.47	4.9	<2	4.86	<2	32	131,000	974
	Feb-13	204	174	79.3	146	14.2	3,040	121,000	15,336
	Mar-13	176	80.5	38.7	87.7	8.84	1,370	109,000	6,064
	Jul-13	<2.22	<2.22	<2.22	<2.22	<2.22	866	5,590	1,478

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	–	
MW-13S	Mar-09	237	137	1530	27	127	NS	NA
	Jun-09	366	105	1500	45	127	NS	NA
	Sep-09	251	244	2190	33	253	NS	NA
	Dec-09	123	89.6	946	14	82.5	NS	NA
	Sep-10	155	154	815	21.3	146	NS	NA
	Mar-11	197	84.7	319	44.6	81.5	NS	NA
	Sep-11	127	164	647	19.6	142	NS	NA
	Mar-12	340	115	510	41.4	100	NS	1246
	Oct-12	247	116	714	32.1	99.9	1510	1406
	Feb-13	25.7	88.3	2290	<20.0	<60.0	1450	2583
	Mar-13	34.5	124	3040	77.5	277	2220	4233
	Jul-13	557	124	2400	155	259	4730	3715

LEGEND:

MW-13S OVERBURDEN GROUNDWATER MONITORING WELL

— PL —— PL — POWER LINE

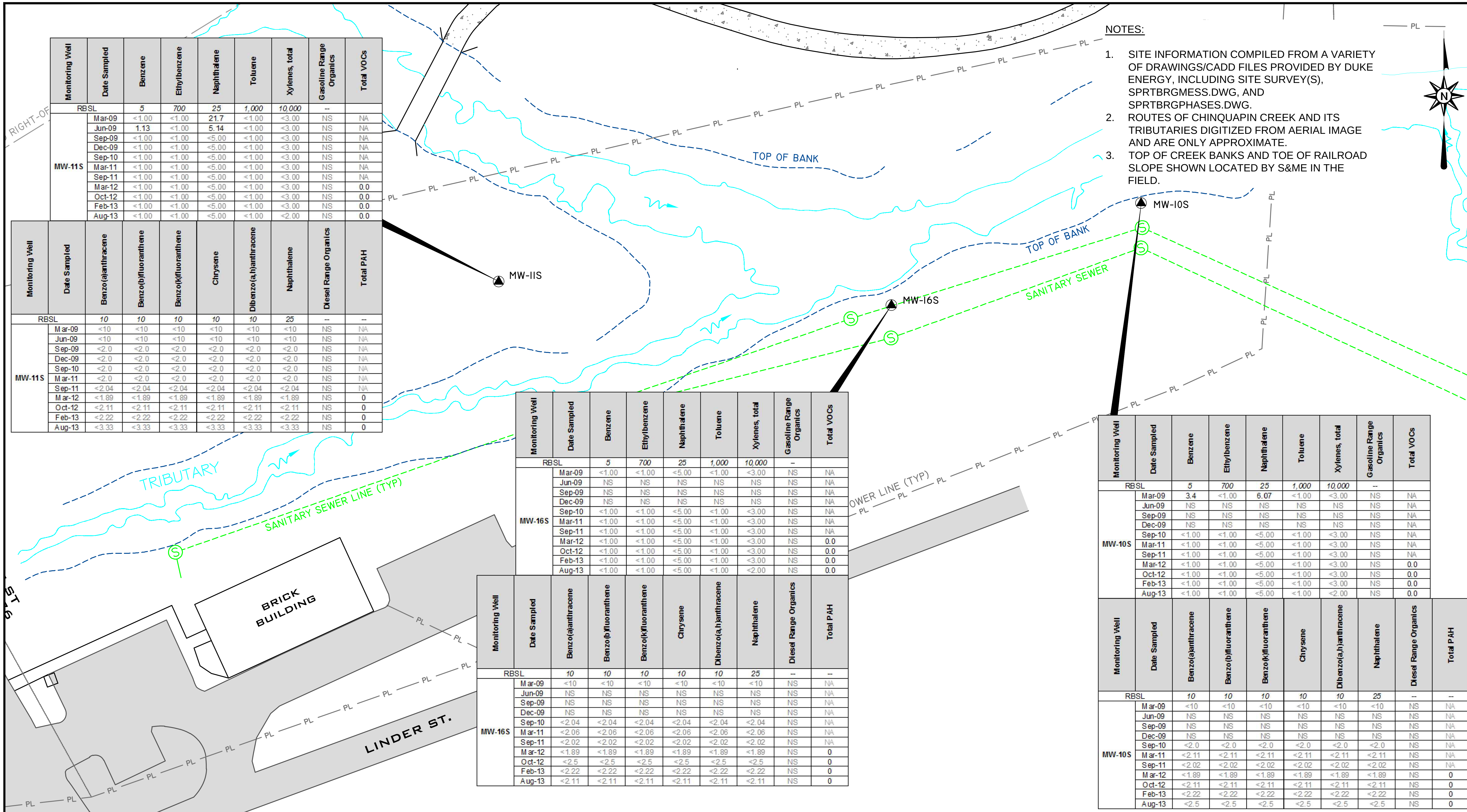
AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

CLIENT: DUKE ENERGY

TITLE: HISTORIC GROUNDWATER RESULTS
SHALLOW WELLS PHASE 1
AREA SOUTH OF ROAD
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021	
CHK: ALA	DATE: 10/29/2013	DWG NO. NA	
SCALE: 0' 50'		FIGURE. NO.: FIGURE 6	



NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG.
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
MW-11S	Mar-09	<1.00	<1.00	21.7	<1.00	<3.00	NS	NA
	Jun-09	1.13	<1.00	5.14	<1.00	<3.00	NS	NA
	Sep-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Dec-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Aug-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-11S	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	<10	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0
	Aug-13	<3.33	<3.33	<3.33	<3.33	<3.33	<3.33	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	–	
MW-16S	Mar-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Aug-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-16S	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Mar-11	<2.06	<2.06	<2.06	<2.06	<2.06	<2.06	NS	NA
	Sep-11	<2.02	<2.02	<2.02	<2.02	<2.02	<2.02	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0
	Aug-13	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
MW-10S	Mar-09	3.4	<1.00	6.07	<1.00	<3.00	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Aug-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-10S	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Mar-11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	NA
	Sep-11	<2.02	<2.02	<2.02	<2.02	<2.02	<2.02	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0
	Aug-13	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	NS	0

LEGEND:

MW-13S — OVERBURDEN GROUNDWATER MONITORING WELL

— PL —— PL — POWER LINE

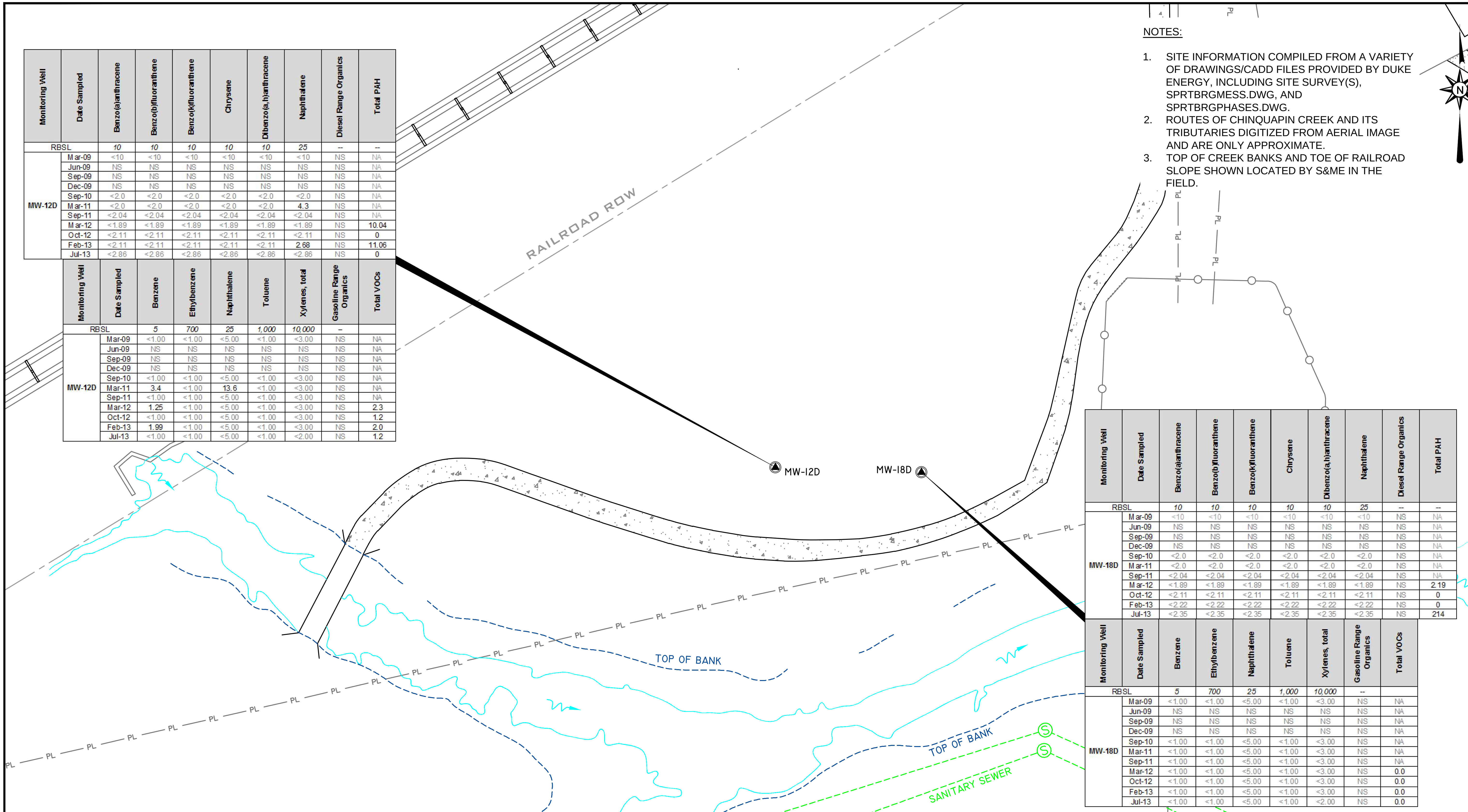
AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE:
HISTORIC GROUNDWATER RESULTS
SHALLOW WELLS PHASE 2 & 3 AREAS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 50'		FIGURE. NO.: FIGURE 7

P:\CADD\Projects\6228\62281220021 Duke Spartanburg SC\F 05 - 10 Tag Maps.dwg Nov. 11, 2013 william.wiers



Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-12D	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	4.3	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	10.04
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Feb-13	<2.11	<2.11	<2.11	<2.11	<2.11	2.68	NS	11.06
	Jul-13	<2.86	<2.86	<2.86	<2.86	<2.86	<2.86	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
MW-12D	Mar-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-11	3.4	<1.00	13.6	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	1.25	<1.00	<5.00	<1.00	<3.00	NS	2.3
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	1.2
	Feb-13	1.99	<1.00	<5.00	<1.00	<3.00	NS	2.0
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	1.2

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-18D	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	2.19
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0
	Jul-13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NS	214

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
MW-18D	Mar-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	NS	NS	NS	NS	NS	NS	NA
	Sep-09	NS	NS	NS	NS	NS	NS	NA
	Dec-09	NS	NS	NS	NS	NS	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG.
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

LEGEND:

MW-13D — BEDROCK GROUNDWATER MONITORING WELL

— PL —— PL — POWER LINE

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

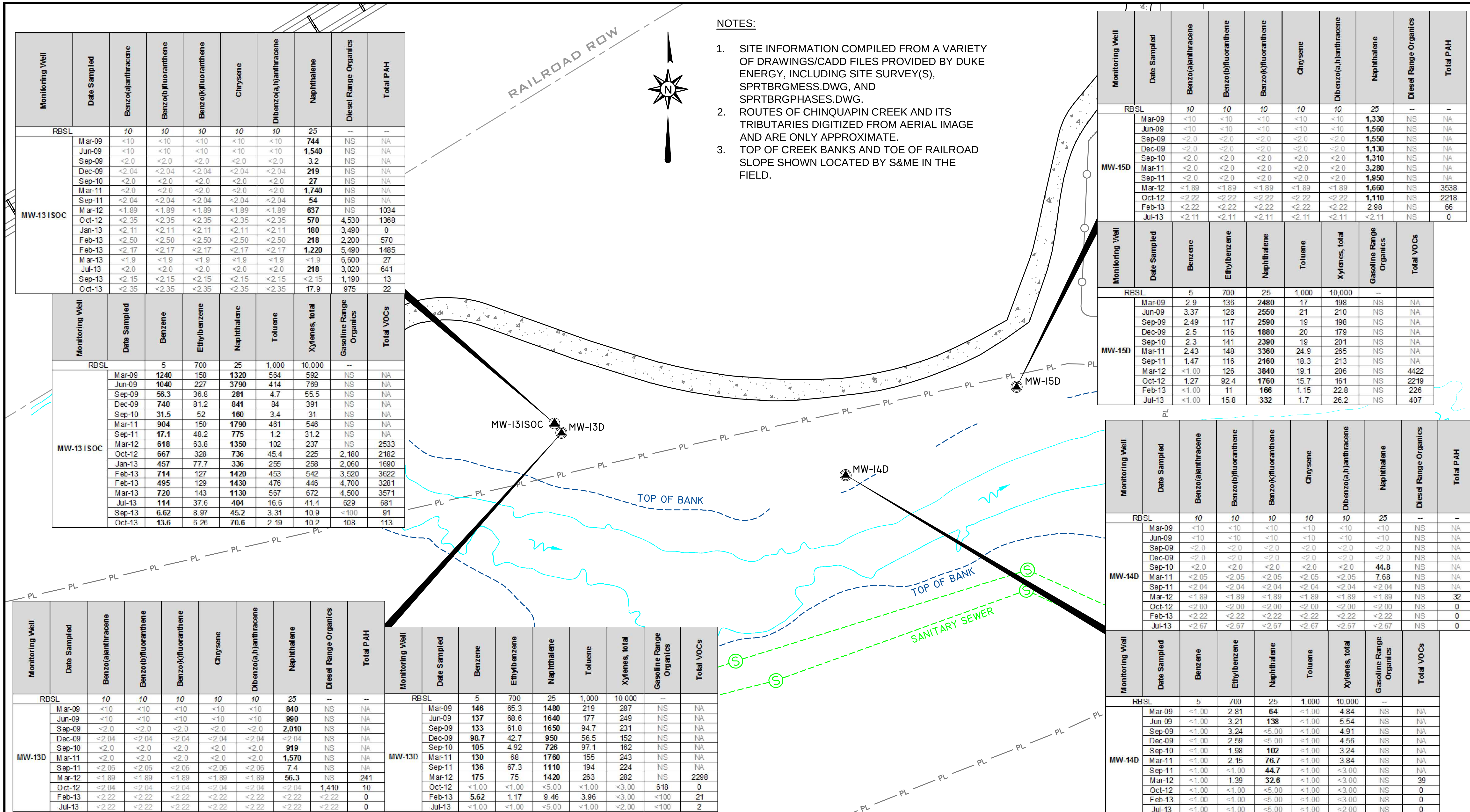
amec

CLIENT: DUKE ENERGY

TITLE: HISTORIC GROUNDWATER RESULTS FOR BEDROCK WELLS PHASE 1
AREA NORTH OF ROAD
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 50'		FIGURE. NO.: FIGURE 8

P:\CADD\Projects\6228\6228120021 Duke Spartanburg SC\F 05 - 10 Tag Maps.dwg Nov. 11, 2013 william.wiers



NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG.
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-13ISOC	Mar-09	<10	<10	<10	<10	<10	**744**	NS	NA
	Jun-09	<10	<10	<10	<10	<10	**1,540**	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	3.2	NS	NA
	Dec-09	<2.04	<2.04	<2.04	<2.04	<2.04	**219**	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	**27**	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	**1,740**	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	**54**	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	**637**	NS	1034
	Oct-12	<2.35	<2.35	<2.35	<2.35	<2.35	**570**	4,530	1368
	Jan-13	<2.11	<2.11	<2.11	<2.11	<2.11	**180**	3,490	0
	Feb-13	<2.50	<2.50	<2.50	<2.50	<2.50	**218**	2,200	570
	Feb-13	<2.17	<2.17	<2.17	<2.17	<2.17	**1,220**	5,490	1485
	Mar-13	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	6,600	27
	Jul-13	<2.0	<2.0	<2.0	<2.0	<2.0	**218**	3,020	641
	Sep-13	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	1,190	13
	Oct-13	<2.35	<2.35	<2.35	<2.35	<2.35	17.9	975	22

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-13ISOC	Mar-09	**1240**	158	**1320**	564	592	NS	NA
	Jun-09	**1040**	227	**3790**	414	769	NS	NA
	Sep-09	**56.3**	36.8	**281**	4.7	55.5	NS	NA
	Dec-09	**740**	81.2	**841**	84	391	NS	NA
	Sep-10	**31.5**	52	**160**	3.4	31	NS	NA
	Mar-11	**904**	150	**1790**	461	546	NS	NA
	Sep-11	**17.1**	48.2	**775**	1.2	31.2	NS	NA
	Mar-12	**618**	63.8	**1350**	102	237	NS	2533
	Oct-12	**667**	328	**736**	45.4	225	2,180	2182
	Jan-13	**457**	77.7	**336**	255	258	2,060	1690
	Feb-13	**714**	127	**1420**	453	542	3,520	3622
	Feb-13	**495**	129	**1430**	476	446	4,700	3281
	Mar-13	**720**	143	**1130**	567	672	4,500	3571
	Jul-13	**114**	37.6	**404**	16.6	41.4	629	681
	Sep-13	**6.62**	8.97	**45.2**	3.31	10.9	<100	91
	Oct-13	**13.6**	6.26	**70.6**	2.19	10.2	108	113

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-15D	Mar-09	<10	<10	<10	<10	<10	**1,330**	NS	NA
	Jun-09	<10	<10	<10	<10	<10	**1,560**	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	**1,550**	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	**1,130**	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	**1,310**	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	**3,280**	NS	NA
	Sep-11	<2.0	<2.0	<2.0	<2.0	<2.0	**1,950**	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	**1,660**	NS	3538
	Oct-12	<2.22	<2.22	<2.22	<2.22	<2.22	**1,110**	NS	2218
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	2.98	NS	66
	Jul-13	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-15D	Mar-09	2.9	136	**2480**	17	198	NS	NA
	Jun-09	3.37	128	**2550**	21	210	NS	NA
	Sep-09	2.49	117	**2590**	19	198	NS	NA
	Dec-09	2.5	116	**1880**	20	179	NS	NA
	Sep-10	2.3	141	**2390**	19	201	NS	NA
	Mar-11	2.43	148	**3360**	24.9	265	NS	NA
	Sep-11	1.47	116	**2160**	18.3	213	NS	NA
	Mar-12	<1.00	126	**3840**	19.1	206	NS	4422
	Oct-12	1.27	92.4	**1760**	15.7	161	NS	2219
	Feb-13	<1.00	11	**166**	1.15	22.8	NS	226
	Jul-13	<1.00	15.8	**332**	1.7	26.2	NS	407

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-14D	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	<10	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	**44.8**	NS	NA
	Mar-11	<2.05	<2.05	<2.05	<2.05	<2.05	7.68	NS	NA
	Sep-11	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	32
	Oct-12	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0
	Jul-13	<2.67	<2.67	<2.67	<2.67	<2.67	<2.67	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-14D	Mar-09	<1.00	2.81	**64**	<1.00	4.84	NS	NA
	Jun-09	<1.00	3.21	**138**	<1.00	5.54	NS	NA
	Sep-09	<1.00	3.24	<5.00	<1.00	4.91	NS	NA
	Dec-09	<1.00	2.59	<5.00	<1.00	4.56	NS	NA
	Sep-10	<1.00	1.98	**102**	<1.00	3.24	NS	NA
	Mar-11	<1.00	2.15	**76.7**	<1.00	3.84	NS	NA
	Sep-11	<1.00	<1.00	**44.7**	<1.00	<3.00	NS	NA
	Mar-12	<1.00	1.39	**32.6**	<1.00	<3.00	NS	39
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
MW-13D	Mar-09	<10	<10	<10	<10	<10	**840**	NS	NA
	Jun-09	<10	<10	<10	<10	<10	**990**	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	**2,010**	NS	NA
	Dec-09	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	**919**	NS	NA
	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	**1,570**	NS	NA
	Sep-11	<2.06	<2.06	<2.06	<2.06	<2.06	7.4	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	**56.3**	NS	241
	Oct-12	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	1,410	10
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	0
	Jul-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		5	700	25	1,000	10,000	--	
MW-13D	Mar-09	**146**	65.3	**1480**	219	287	NS	NA
	Jun-09	**137**	68.6	**1640**	177	249	NS	NA
	Sep-09	**133**	61.8	**1650**	94.7	231	NS	NA
	Dec-09	**98.7**	42.7	**950**	56.5	152	NS	NA
	Sep-10	**105**	4.92	**726**	97.1	162	NS	NA
	Mar-11	**130**	68	**1760**	155	243	NS	NA
	Sep-11	**136**	67.3	**1110**	194	224	NS	NA
	Mar-12	**175**	75	**1420**	263	282	NS	2298
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	618	0
	Feb-13	**5.62**	1.17	9.46	3.96	<3.00	<100	21
	Jul-13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	2

LEGEND:

MW-13ISOC — OVERBURDEN GROUNDWATER MONITORING WELL

MW-13D — BEDROCK GROUNDWATER MONITORING WELL

— PL —— PL — POWER LINE

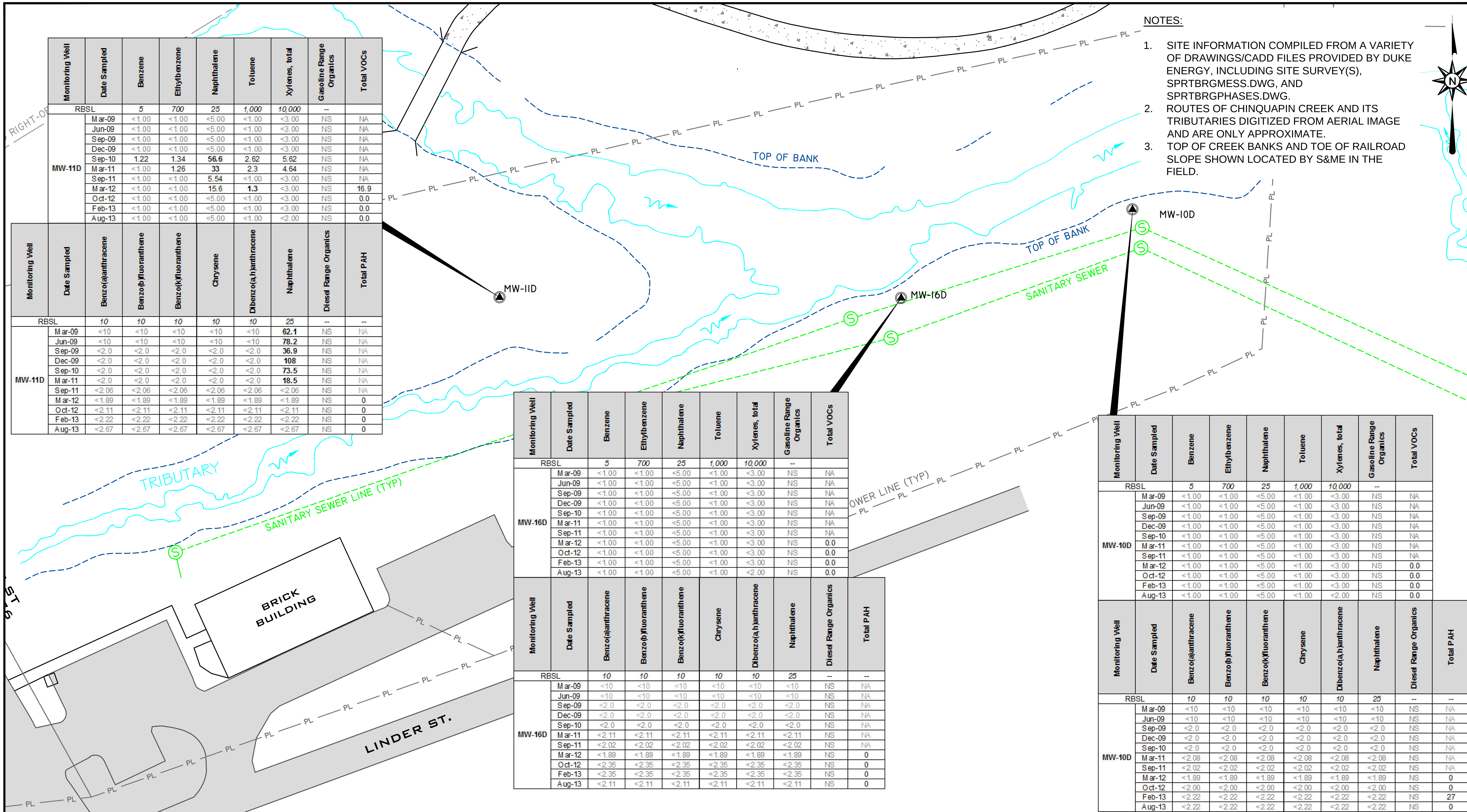
AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE: HISTORIC GROUNDWATER RESULTS FOR BEDROCK/PWR WELLS PHASE 1
AREA SOUTH OF ROAD
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' — 50'		FIGURE. NO.: FIGURE 9

P:\CADD\Projects\6228\6228120021 Duke Spartanburg SC\F 05 - 10 Tag Maps.dwg Nov. 11, 2013 william.wiers



NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG.
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
	Mar-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Dec-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-10	1.22	1.34	**56.6**	2.62	5.62	NS	NA
MW-11D	Mar-11	<1.00	1.26	**33**	2.3	4.64	NS	NA
	Sep-11	<1.00	<1.00	5.54	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	15.6	**1.3**	<3.00	NS	16.9
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Aug-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
	Mar-09	<10	<10	<10	<10	<10	**62.1**	NS	NA
	Jun-09	<10	<10	<10	<10	<10	**78.2**	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	**36.9**	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	**108**	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	**73.5**	NS	NA
MW-11D	Mar-11	<2.0	<2.0	<2.0	<2.0	<2.0	**18.5**	NS	NA
	Sep-11	<2.06	<2.06	<2.06	<2.06	<2.06	<2.06	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0
	Aug-13	<2.67	<2.67	<2.67	<2.67	<2.67	<2.67	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
	Mar-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Dec-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
MW-16D	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Aug-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	<10	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
MW-16D	Mar-11	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	NA
	Sep-11	<2.02	<2.02	<2.02	<2.02	<2.02	<2.02	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NS	0
	Feb-13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	NS	0
	Aug-13	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	NS	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
	Mar-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Jun-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Dec-09	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-10	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
MW-10D	Mar-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Sep-11	<1.00	<1.00	<5.00	<1.00	<3.00	NS	NA
	Mar-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Oct-12	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Feb-13	<1.00	<1.00	<5.00	<1.00	<3.00	NS	0.0
	Aug-13	<1.00	<1.00	<5.00	<1.00	<2.00	NS	0.0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
	Mar-09	<10	<10	<10	<10	<10	<10	NS	NA
	Jun-09	<10	<10	<10	<10	<10	<10	NS	NA
	Sep-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Dec-09	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
	Sep-10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NA
MW-10D	Mar-11	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	NS	NA
	Sep-11	<2.02	<2.02	<2.02	<2.02	<2.02	<2.02	NS	NA
	Mar-12	<1.89	<1.89	<1.89	<1.89	<1.89	<1.89	NS	0
	Oct-12	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	NS	0
	Feb-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	27
	Aug-13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	NS	0

LEGEND:

MW-13D — BEDROCK GROUNDWATER MONITORING WELL

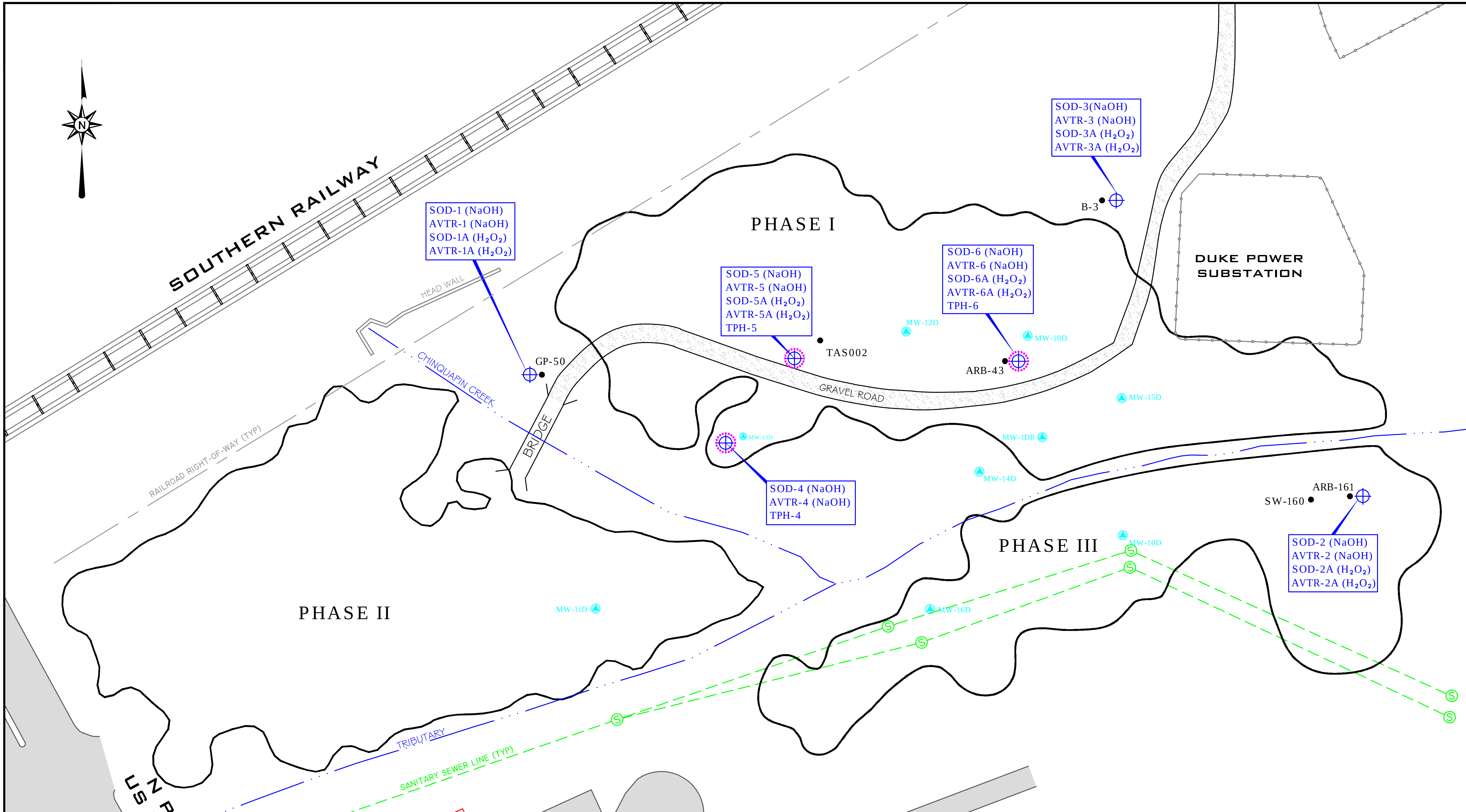
— PL — PL — POWER LINE

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE: HISTORIC GROUNDWATER RESULTS
BEDROCK WELLS PHASE 2 & 3 AREAS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 50'		FIGURE. NO.: FIGURE 10



LEGEND

PROPERTY BOUNDARY LINE	HISTORICAL SAMPLE LOCATION
RAILROAD RIGHT-OF-WAY	TOTAL PETROLEUM HYDROCARBON SAMPLE LOCATION (LOCATIONS 4,5,6)
CREEK/TRIBUTARY	SOIL OXIDANT DEMAND (SOD) AND ACTIVATOR DEMAND (AVTR) SAMPLE LOCATION
PL OVERHEAD POWER	MW-13D BEDROCK GROUNDWATER MONITORING WELL
UNDERGROUND SANITARY SEWER	MW-1DR DEEP BEDROCK GROUNDWATER MONITORING WELL
S SANITARY SEWER MANHOLE	APPROXIMATE LIMITS OF EXCAVATION REMEDIATION (PHASE I = PHASE I EXCAVATION)

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

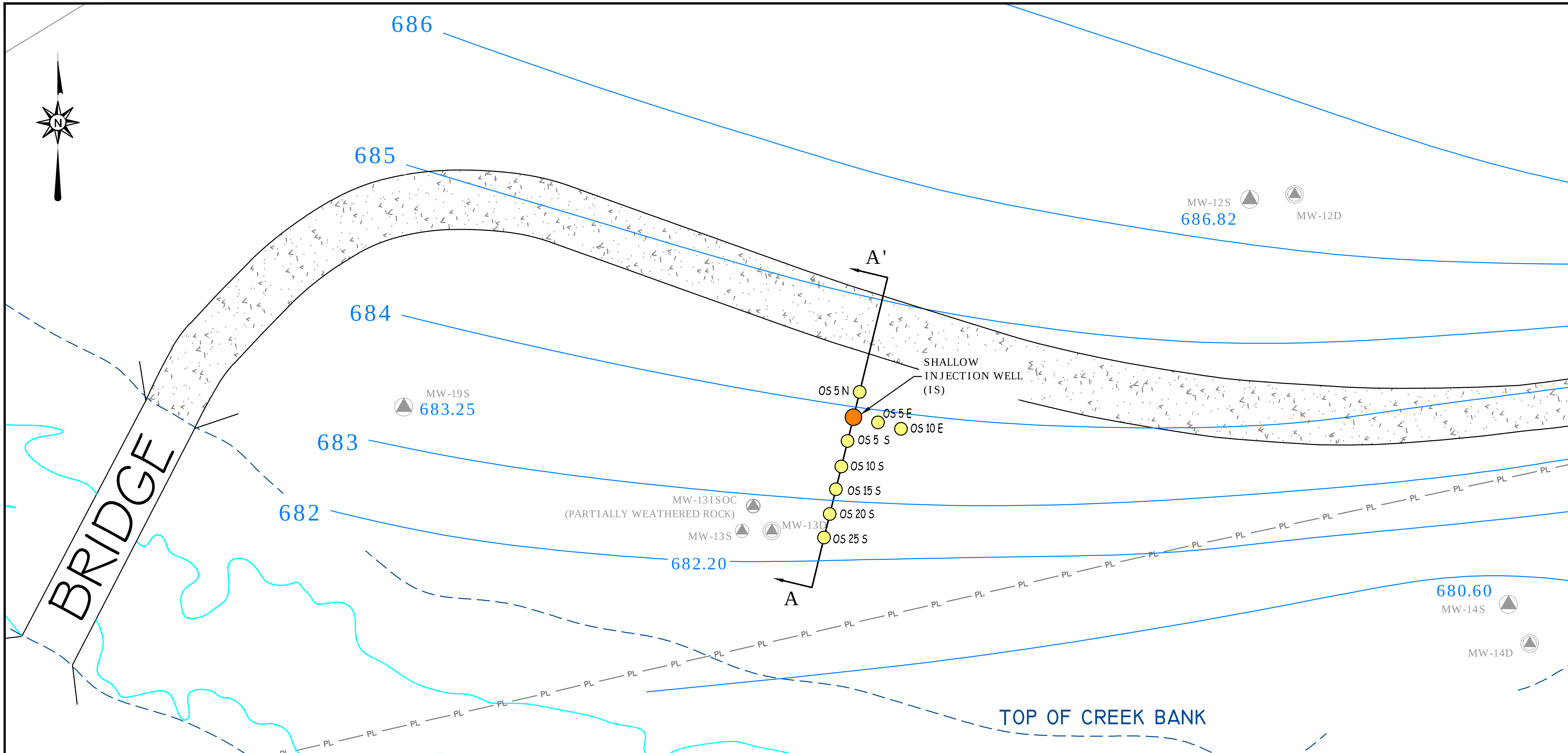
amec

CLIENT: DUKE ENERGY

TITLE: SOIL OXIDANT, ACTIVATOR DEMAND, AND TPH SAMPLE LOCATIONS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 60'		FIGURE. NO.: FIGURE 11

P:\CADD\Projects\6228\6228120021 Duke Spartanburg SC\F 11 Soil Oxidant and Activator Sample Loc.dwg Nov. 11, 2013 william.wers



LEGEND:

MW-13S	▲	OVERBURDEN GROUNDWATER MONITORING WELL
MW-13D	▲	BEDROCK GROUNDWATER MONITORING WELL
MW-13ISOC	▲	PARTIALLY WEATHERED ROCK GROUNDWATER MONITORING WELL
IS	●	OVERBURBEN INJECTION WELL
OS 10 S	●	OVERBURDEN OBSERVATION WELL / DISTANCE IN FEET FROM INJECTION POINT / DIRECTION FROM INJECTION POINT

—685— SHALLOW POTENTIOMETRIC SURFACE, IN FEET

—PL— POWER LINE

NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG.
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

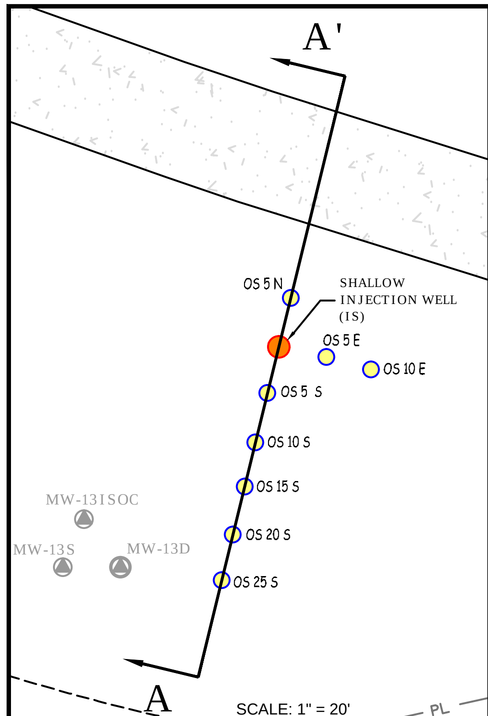
amec

CLIENT: DUKE ENERGY

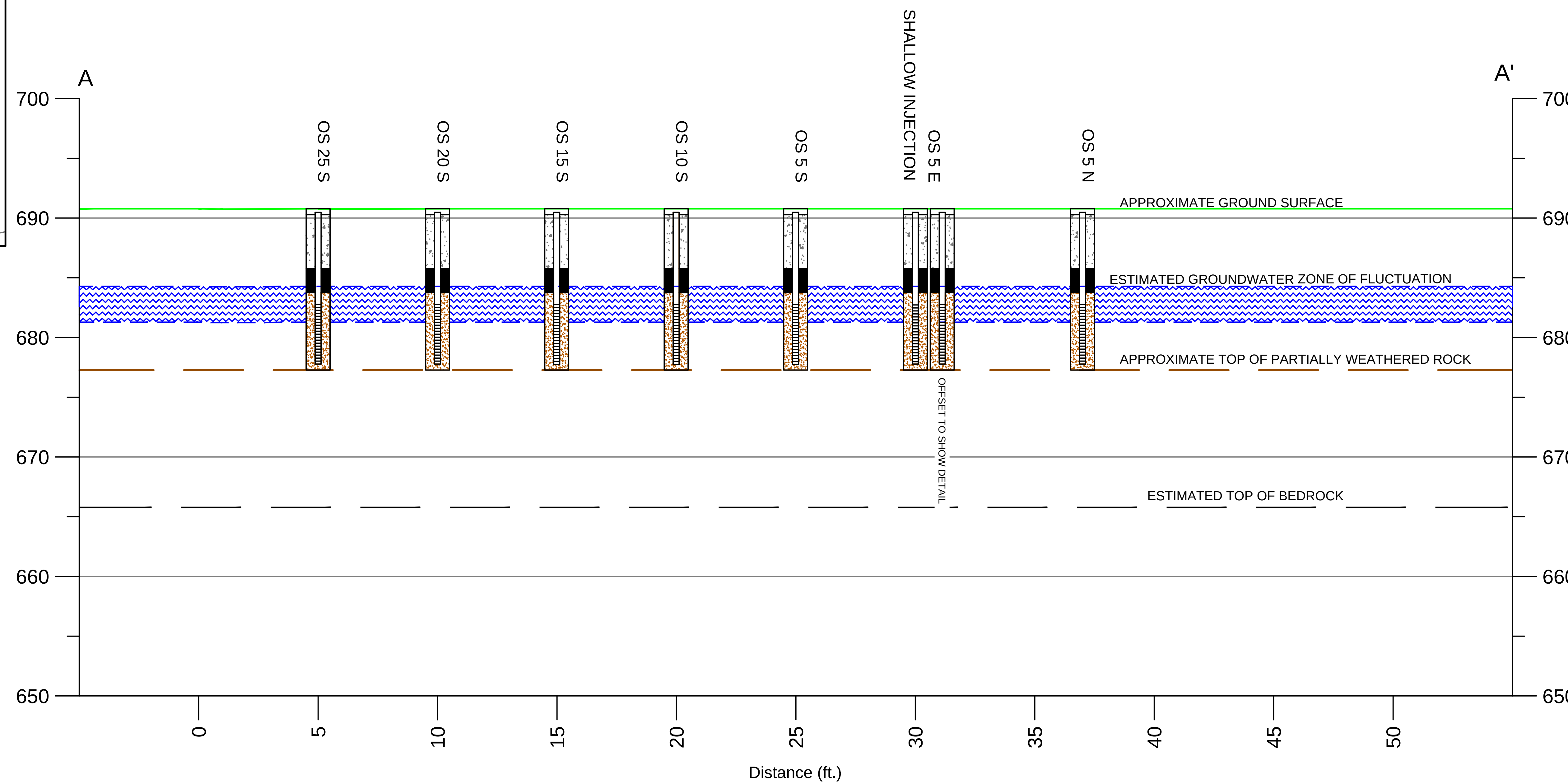
TITLE: SITE PLAN SHALLOW INJECTION AND OBSERVATION WELL LOCATIONS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 20'		FIGURE. NO.: FIGURE 12

P:\CADD\Projects\6228\6228120021 Duke Spartanburg SC\F 12 Site Plan Shallow Inj and Observation Wells.dwg Nov. 11, 2013 william.wiers



CROSS SECTION A-A'



LEGEND:

Grout

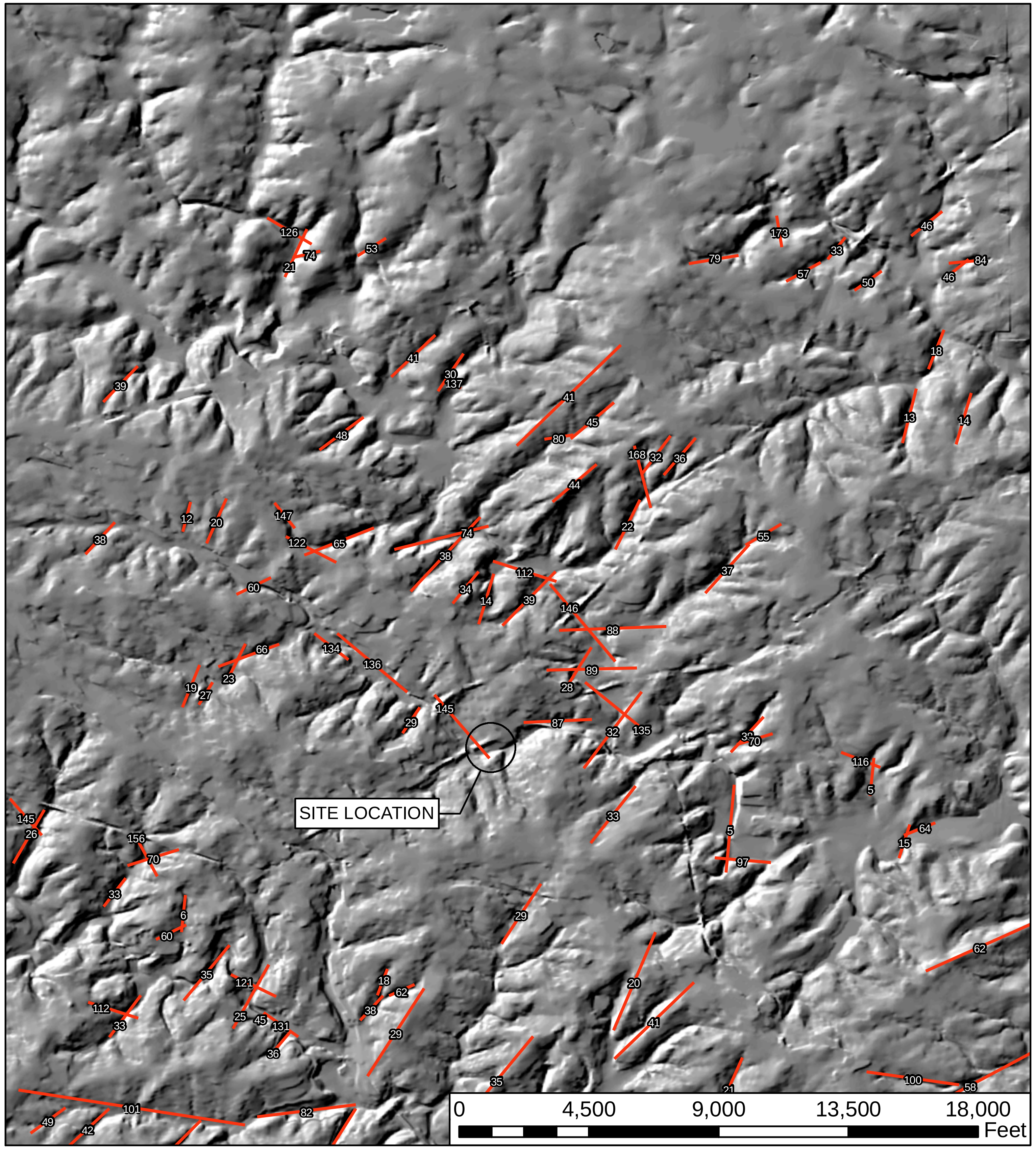
Bentonite Seal

Sand Filter Pack

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

CLIENT: DUKE ENERGY			
TITLE: CROSS SECTION OF OVERBURDEN INJECTION AND OBSERVATION POINTS DUKE ENERGY PINE STREET MGP SITE SPARTANBURG, SOUTH CAROLINA	DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
	CHK: ALA	DATE: 10/29/2013	DWG NO. NA
	SCALE:	AS SHOWN	FIGURE. NO.: FIGURE 13



LEGEND

- Lineaments
- Transect Line
- 97 Compass Angle (Azimuth) clockwise from due north

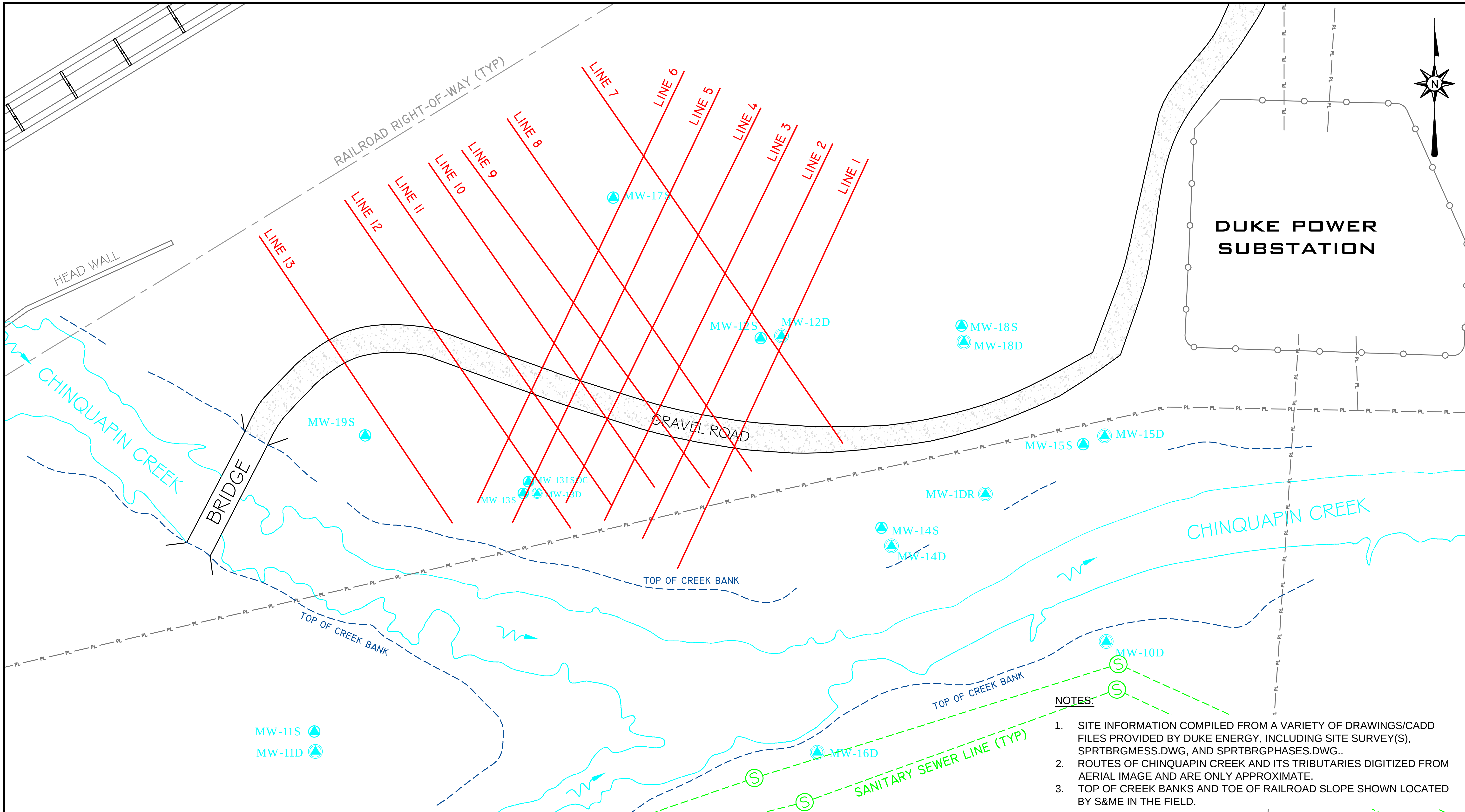
AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

CLIENT: DUKE ENERGY

TITLE:
FRACTURE TRACE ANALYSIS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: JBO	REV:	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 11/8/2013	FILE: Duke_Energy_Spartanburg_SC_Lineament_Analysis_nov2013.mxd
SCALE: AS SHOWN		FIGURE NO.: 14



NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG..
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

LEGEND:

MW-13S	SHALLOW GROUNDWATER MONITORING WELL
MW-13ISOC	PARTIALLY WEATHERED ROCK GROUNDWATER MONITORING WELL
MW-13D	BEDROCK GROUNDWATER MONITORING WELL

0' 20' 40' 60'
1" = 40'

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

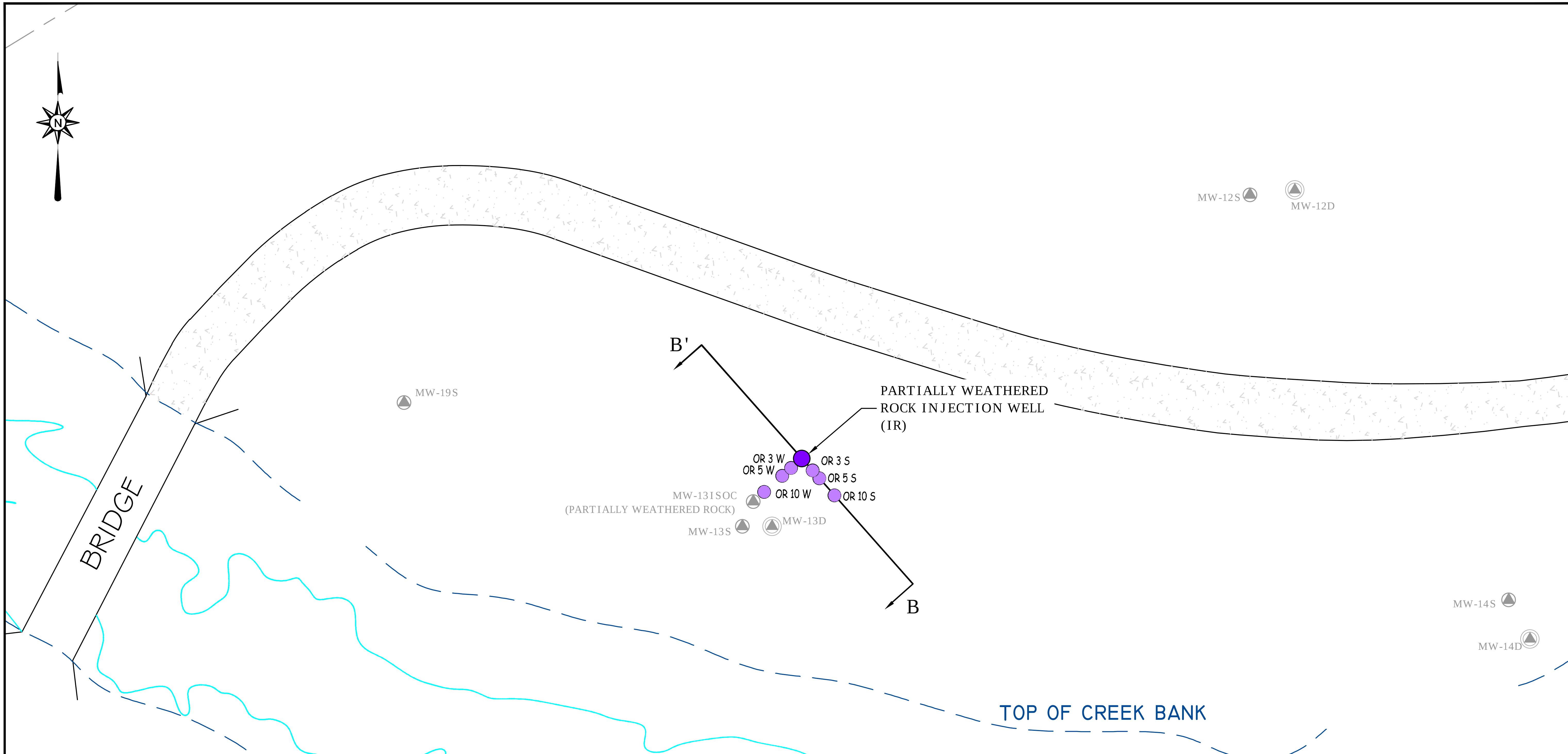
amec

CLIENT: DUKE ENERGY

TITLE: TRANSECT LINE LOCATIONS FOR SP SURVEY
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 40'		FIGURE NO.: FIGURE 15

P:\CADD\Projects\6228\62281200021 Duke Spartanburg SC\F 15 Transect Line Locations SP Survey.dwg Nov. 11, 2013 william.wiers



LEGEND:

MW-13S	▲	OVERBURDEN GROUNDWATER MONITORING WELL
MW-13D	▲	BEDROCK GROUNDWATER MONITORING WELL
MW-13ISOC	▲	PARTIALLY WEATHERED ROCK GROUNDWATER MONITORING WELL
IR	●	PARTIALLY WEATHERED ROCK INJECTION WELL
OR 10 S	●	PARTIALLY WEATHERED ROCK OBSERVATION WELL / DISTANCE IN FEET FROM INJECTION POINT / DIRECTION FROM INJECTION POINT

NOTES:

1. SITE INFORMATION COMPILED FROM A VARIETY OF DRAWINGS/CADD FILES PROVIDED BY DUKE ENERGY, INCLUDING SITE SURVEY(S), SPRTBRGMESS.DWG, AND SPRTBRGPHASES.DWG.
2. ROUTES OF CHINQUAPIN CREEK AND ITS TRIBUTARIES DIGITIZED FROM AERIAL IMAGE AND ARE ONLY APPROXIMATE.
3. TOP OF CREEK BANKS AND TOE OF RAILROAD SLOPE SHOWN LOCATED BY S&ME IN THE FIELD.

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

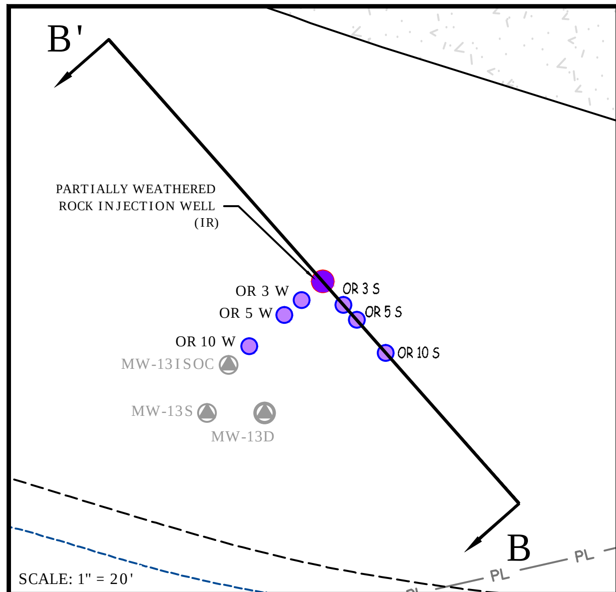
amec

CLIENT: DUKE ENERGY

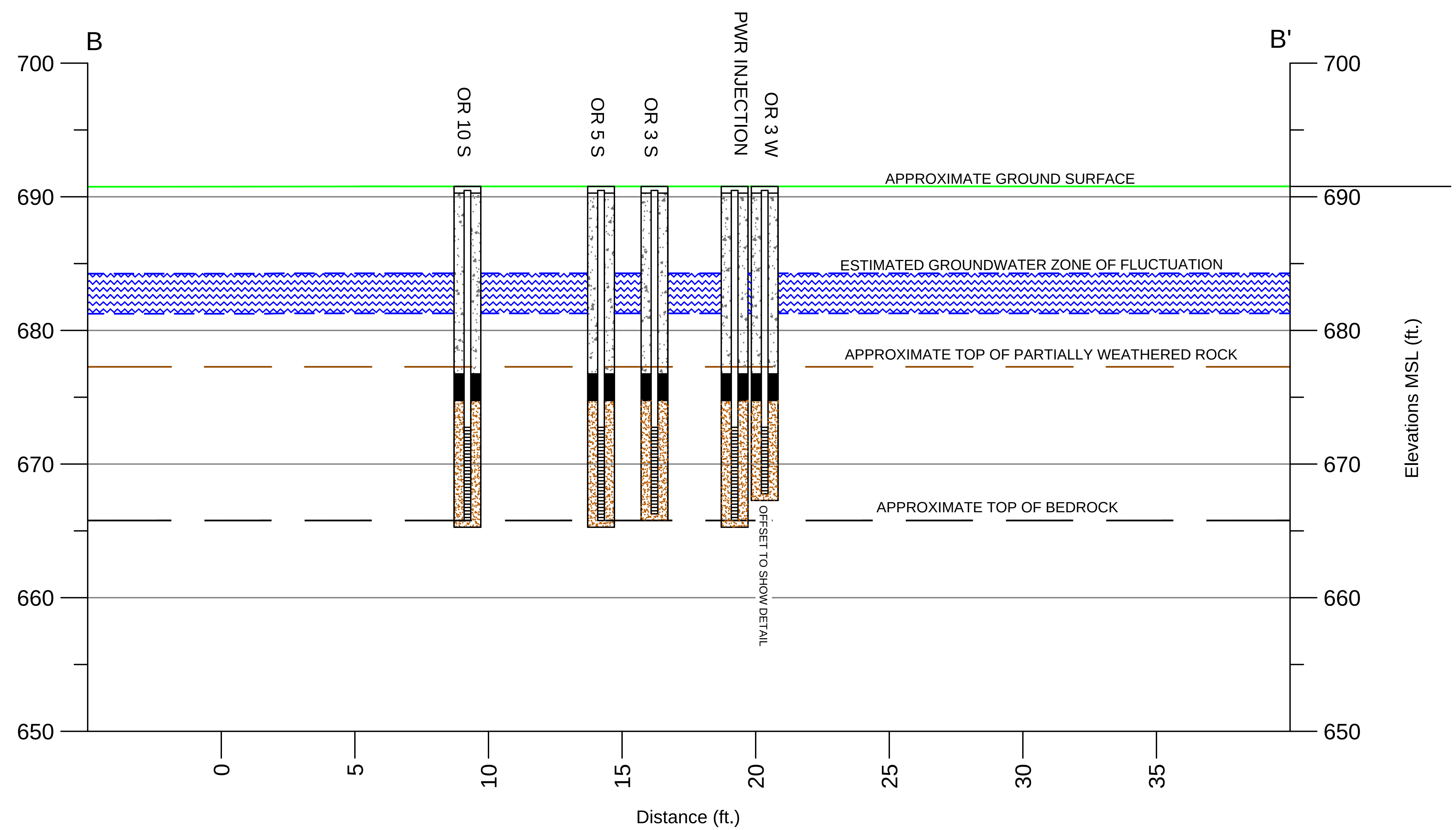
TITLE: SITE PLAN PWR INJECTION AND OBSERVATION WELL LOCATIONS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 20'		FIGURE NO.: FIGURE 16

P:\CADD\Projects\6228\622812002\1 Duke Spartanburg SC\F 16 Site Plan PWR Inj and Observ Well Loc.dwg Nov. 11, 2013 william.wiers



CROSS SECTION B-B'



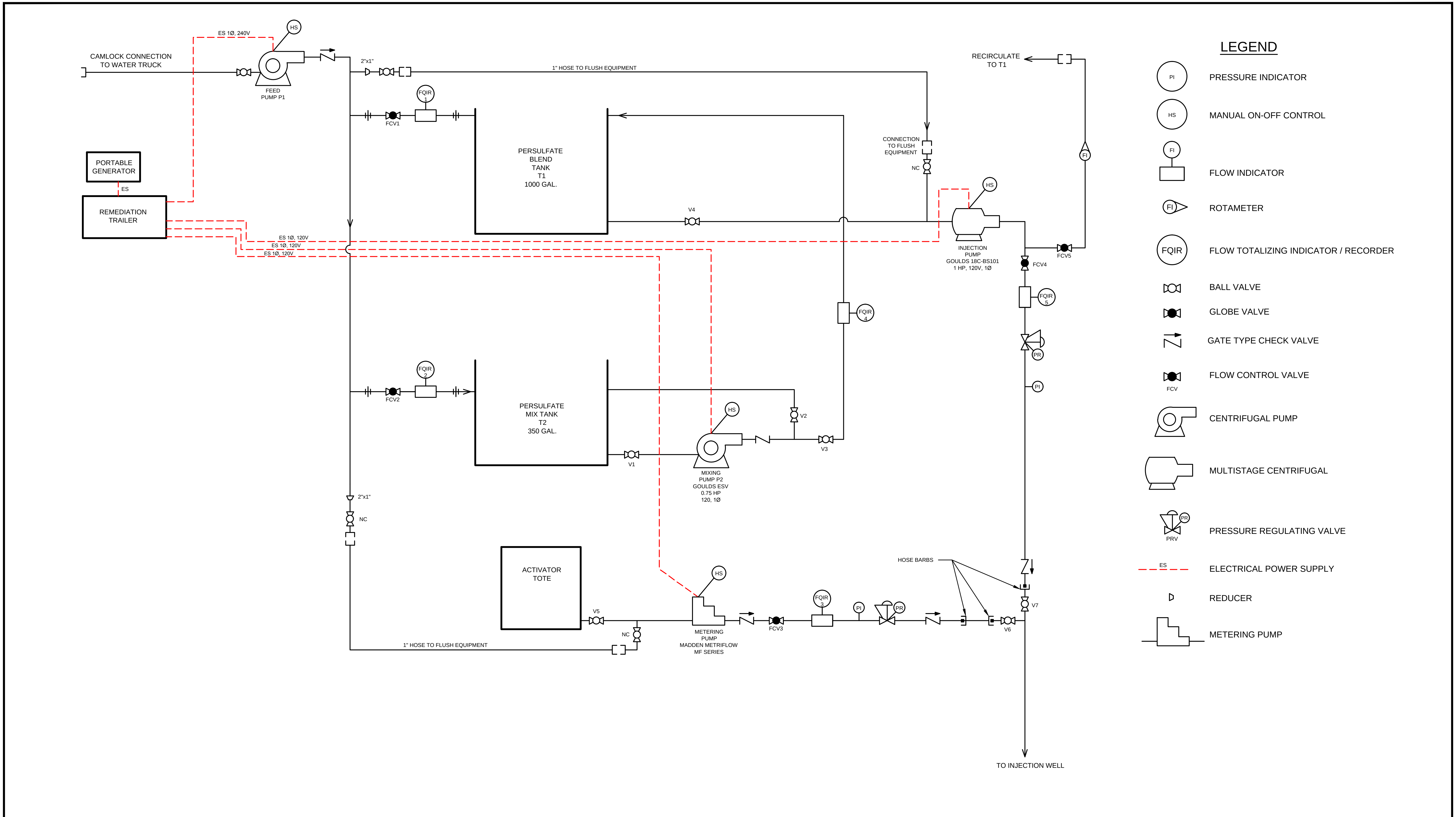
LEGEND:

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE: CROSS SECTION OF PWR INJECTION AND OBSERVATION POINTS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: WRW	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: AS SHOWN		FIGURE. NO.: FIGURE 17



NOTES:

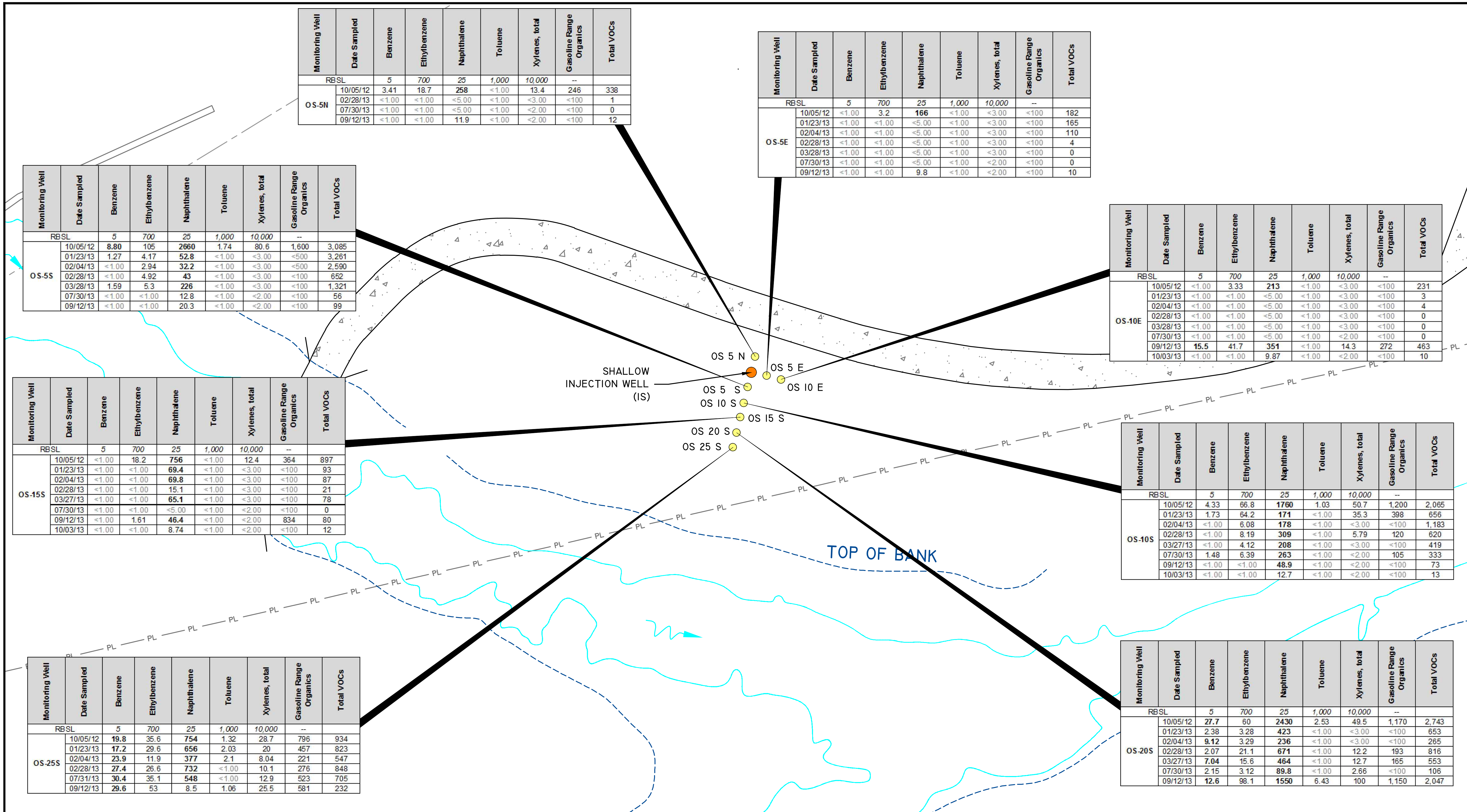
1. FQIR1 RECORDS TOTAL FLOW TO T1 AND T2. T1 & T2 ARE NOT OPERATED SIMULTANEOUSLY. FQIR 1 IS RESET FOR INJECTATE MAKE-UP IN T1 AFTER CONCENTRATE BLENDING IN T2.
2. V1 & V2 CLOSED FOR INITIAL BLENDING IN T2. OPEN V1, V2, V3 TO TRANSFER TO T1. V4 CLOSED FOR INJECTATE BLENDING, V2 AND V3 CLOSE FOR INJECTION, V4 OPEN FOR INJECTION.
3. V5 AND V6 OPEN FOR NaOH BLENDING. CLOSE V6, OPEN V5 AND V7 FOR NaOH INJECTION.

AMEC Environment & Infrastructure
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE: PROCESS INSTRUMENT DIAGRAM FOR PILOT TEST INJECTIONS
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: JP	PROJ. NO.: 6228-12-0021
CHK: WPT	DATE: 10-05-2012	DWG NO. 6228-12-0021-12
SCALE: NOT TO SCALE		FIGURE 18



Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-5N	10/05/12	3.41	18.7	**258**	<1.00	13.4	246	338
	02/28/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	1
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	0
	09/12/13	<1.00	<1.00	11.9	<1.00	<2.00	<100	12

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-5E	10/05/12	<1.00	3.2	**166**	<1.00	<3.00	<100	182
	01/23/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	165
	02/04/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	110
	02/28/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	4
	03/28/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	0
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	0
	09/12/13	<1.00	<1.00	9.8	<1.00	<2.00	<100	10

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-5S	10/05/12	**8.80**	105	**2660**	1.74	80.6	1,600	3,085
	01/23/13	1.27	4.17	**52.8**	<1.00	<3.00	<500	3,261
	02/04/13	<1.00	2.94	**32.2**	<1.00	<3.00	<500	2,590
	02/28/13	<1.00	4.92	**43**	<1.00	<3.00	<100	652
	03/28/13	1.59	5.3	**226**	<1.00	<3.00	<100	1,321
	07/30/13	<1.00	<1.00	12.8	<1.00	<2.00	<100	56
	09/12/13	<1.00	<1.00	20.3	<1.00	<2.00	<100	99

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-10E	10/05/12	<1.00	3.33	**213**	<1.00	<3.00	<100	231
	01/23/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	3
	02/04/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	4
	02/28/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	0
	03/28/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	0
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	0
	09/12/13	**15.5**	41.7	**351**	<1.00	14.3	272	463
	10/03/13	<1.00	<1.00	9.87	<1.00	<2.00	<100	10

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-15S	10/05/12	<1.00	18.2	**756**	<1.00	12.4	364	897
	01/23/13	<1.00	<1.00	**69.4**	<1.00	<3.00	<100	93
	02/04/13	<1.00	<1.00	**69.8**	<1.00	<3.00	<100	87
	02/28/13	<1.00	<1.00	15.1	<1.00	<3.00	<100	21
	03/27/13	<1.00	<1.00	**65.1**	<1.00	<3.00	<100	78
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	0
	09/12/13	<1.00	1.61	**46.4**	<1.00	<2.00	834	80
	10/03/13	<1.00	<1.00	8.74	<1.00	<2.00	<100	12

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-10S	10/05/12	4.33	66.8	**1760**	1.03	50.7	1,200	2,065
	01/23/13	1.73	64.2	**171**	<1.00	35.3	398	656
	02/04/13	<1.00	6.08	**178**	<1.00	<3.00	<100	1,183
	02/28/13	<1.00	8.19	**309**	<1.00	5.79	120	620
	03/27/13	<1.00	4.12	**208**	<1.00	<3.00	<100	419
	07/30/13	1.48	6.39	**263**	<1.00	<2.00	105	333
	09/12/13	<1.00	<1.00	**48.9**	<1.00	<2.00	<100	73
	10/03/13	<1.00	<1.00	12.7	<1.00	<2.00	<100	13

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-25S	10/05/12	**19.8**	35.6	**754**	1.32	28.7	796	934
	01/23/13	**17.2**	29.6	**656**	2.03	20	457	823
	02/04/13	**23.9**	11.9	**377**	2.1	8.04	221	547
	02/28/13	**27.4**	26.6	**732**	<1.00	10.1	276	848
	07/31/13	**30.4**	35.1	**548**	<1.00	12.9	523	705
	09/12/13	**29.6**	53	8.5	1.06	25.5	581	232

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OS-20S	10/05/12	**27.7**	60	**2430**	2.53	49.5	1,170	2,743
	01/23/13	2.38	3.28	**423**	<1.00	<3.00	<100	653
	02/04/13	**9.12**	3.29	**236**	<1.00	<3.00	<100	265
	02/28/13	2.07	21.1	**671**	<1.00	12.2	193	816
	03/27/13	**7.04**	15.6	**464**	<1.00	12.7	165	553
	07/30/13	2.15	3.12	**89.8**	<1.00	2.66	<100	106
	09/12/13	**12.6**	98.1	**1550**	6.43	100	1,150	2,047

LEGEND:

IS — OVERBURDEN GROUNDWATER INJECTION WELL

OS 10 S — OVERBURDEN OBSERVATION WELL / DISTANCE IN FEET FROM INJECTION POINT / DIRECTION FROM INJECTION POINT

— PL —— PL — POWER LINE

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

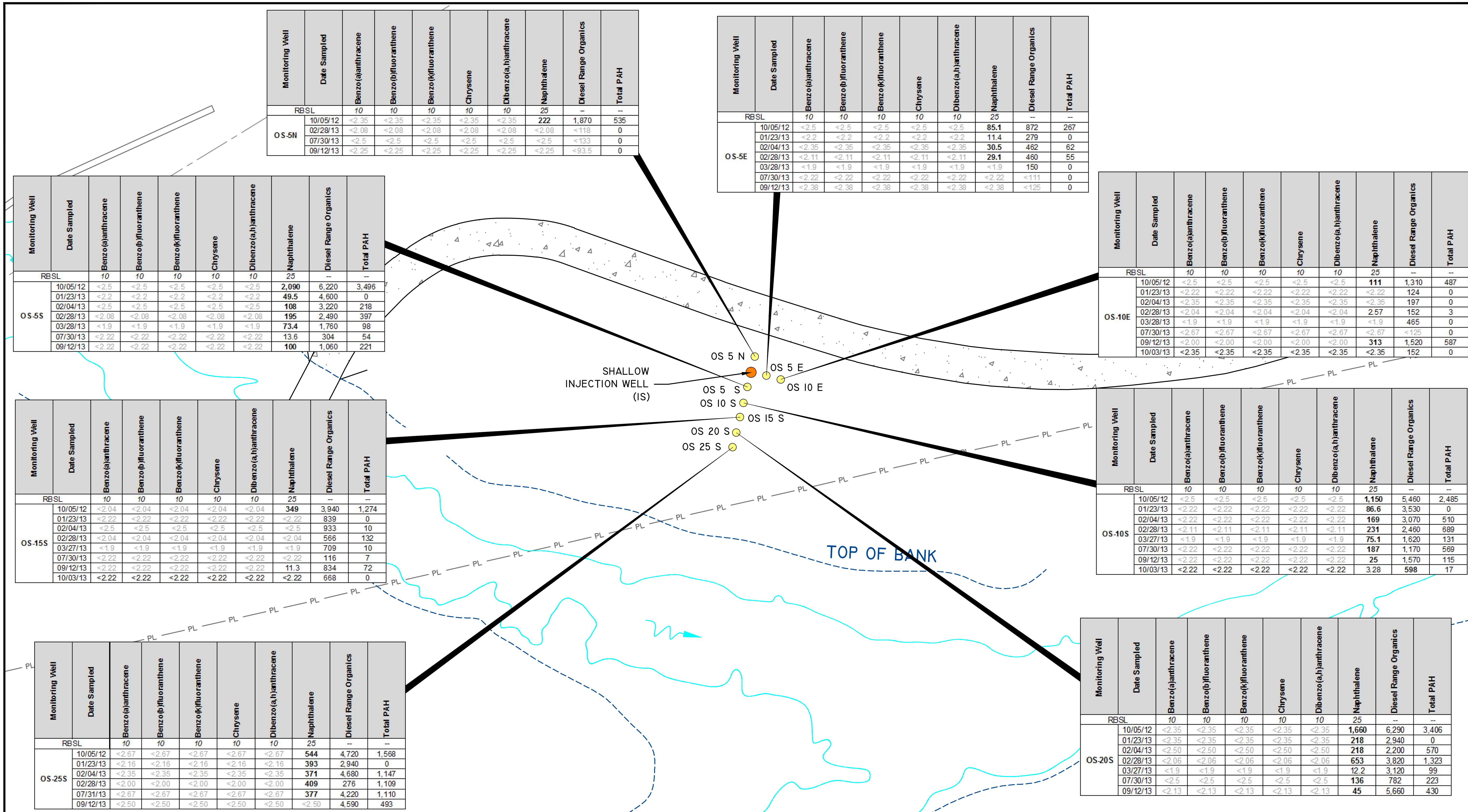
CLIENT: DUKE ENERGY

TITLE: HISTORIC VOC PERFORMANCE MONITORING RESULTS
SHALLOW WELLS - PILOT AREA
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT | REV: WPT | PROJ. NO.: 6228-12-0021

CHK: ALA | DATE: 10/29/2013 | DWG NO. NA

SCALE: 0' 30' | FIGURE. NO.: FIGURE 19



Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-5N	10/05/12	<2.35	<2.35	<2.35	<2.35	<2.35	**222**	1,870	535
	02/28/13	<2.08	<2.08	<2.08	<2.08	<2.08	<2.08	<118	0
	07/30/13	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<133	0
	09/12/13	<2.25	<2.25	<2.25	<2.25	<2.25	<2.25	<93.5	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-5E	10/05/12	<2.5	<2.5	<2.5	<2.5	<2.5	**85.1**	872	267
	01/23/13	<2.2	<2.2	<2.2	<2.2	<2.2	11.4	279	0
	02/04/13	<2.35	<2.35	<2.35	<2.35	<2.35	**30.5**	462	62
	02/28/13	<2.11	<2.11	<2.11	<2.11	<2.11	**29.1**	460	55
	03/28/13	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	150	0
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<111	0
	09/12/13	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	<125	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-5S	10/05/12	<2.5	<2.5	<2.5	<2.5	<2.5	**2,090**	6,220	3,496
	01/23/13	<2.2	<2.2	<2.2	<2.2	<2.2	**49.5**	4,600	0
	02/04/13	<2.5	<2.5	<2.5	<2.5	<2.5	**108**	3,220	218
	02/28/13	<2.08	<2.08	<2.08	<2.08	<2.08	**195**	2,490	397
	03/28/13	<1.9	<1.9	<1.9	<1.9	<1.9	**73.4**	1,760	98
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	13.6	304	54
	09/12/13	<2.22	<2.22	<2.22	<2.22	<2.22	**100**	1,060	221

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-10E	10/05/12	<2.5	<2.5	<2.5	<2.5	<2.5	**111**	1,310	487
	01/23/13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	124	0
	02/04/13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	197	0
	02/28/13	<2.04	<2.04	<2.04	<2.04	<2.04	2.57	152	3
	03/28/13	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	465	0
	07/30/13	<2.67	<2.67	<2.67	<2.67	<2.67	<2.67	<125	0
	09/12/13	<2.00	<2.00	<2.00	<2.00	<2.00	**313**	1,520	587
	10/03/13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	152	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-15S	10/05/12	<2.04	<2.04	<2.04	<2.04	<2.04	**349**	3,940	1,274
	01/23/13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	839	0
	02/04/13	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	933	10
	02/28/13	<2.04	<2.04	<2.04	<2.04	<2.04	<2.04	566	132
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	709	10
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	116	7
	09/12/13	<2.22	<2.22	<2.22	<2.22	<2.22	11.3	834	72
	10/03/13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	668	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-10S	10/05/12	<2.5	<2.5	<2.5	<2.5	<2.5	**1,150**	5,460	2,485
	01/23/13	<2.22	<2.22	<2.22	<2.22	<2.22	**86.6**	3,530	0
	02/04/13	<2.22	<2.22	<2.22	<2.22	<2.22	**169**	3,070	510
	02/28/13	<2.11	<2.11	<2.11	<2.11	<2.11	**231**	2,460	689
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	**75.1**	1,620	131
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	**187**	1,170	569
	09/12/13	<2.22	<2.22	<2.22	<2.22	<2.22	**25**	1,570	115
	10/03/13	<2.22	<2.22	<2.22	<2.22	<2.22	3.28	**598**	17

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-25S	10/05/12	<2.67	<2.67	<2.67	<2.67	<2.67	**544**	4,720	1,568
	01/23/13	<2.16	<2.16	<2.16	<2.16	<2.16	**393**	2,940	0
	02/04/13	<2.35	<2.35	<2.35	<2.35	<2.35	**371**	4,680	1,147
	02/28/13	<2.00	<2.00	<2.00	<2.00	<2.00	**409**	276	1,109
	07/31/13	<2.67	<2.67	<2.67	<2.67	<2.67	**377**	4,220	1,110
	09/12/13	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	4,590	493

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OS-20S	10/05/12	<2.35	<2.35	<2.35	<2.35	<2.35	**1,660**	6,290	3,406
	01/23/13	<2.35	<2.35	<2.35	<2.35	<2.35	**218**	2,940	0
	02/04/13	<2.50	<2.50	<2.50	<2.50	<2.50	**218**	2,200	570
	02/28/13	<2.06	<2.06	<2.06	<2.06	<2.06	**653**	3,820	1,323
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	12.2	3,120	99
	07/30/13	<2.5	<2.5	<2.5	<2.5	<2.5	**136**	782	223
	09/12/13	<2.13	<2.13	<2.13	<2.13	<2.13	**45**	5,660	430

LEGEND:

IS — OVERBURDEN GROUNDWATER INJECTION WELL

OS 10 S — OVERBURDEN OBSERVATION WELL / DISTANCE IN FEET FROM INJECTION POINT / DIRECTION FROM INJECTION POINT

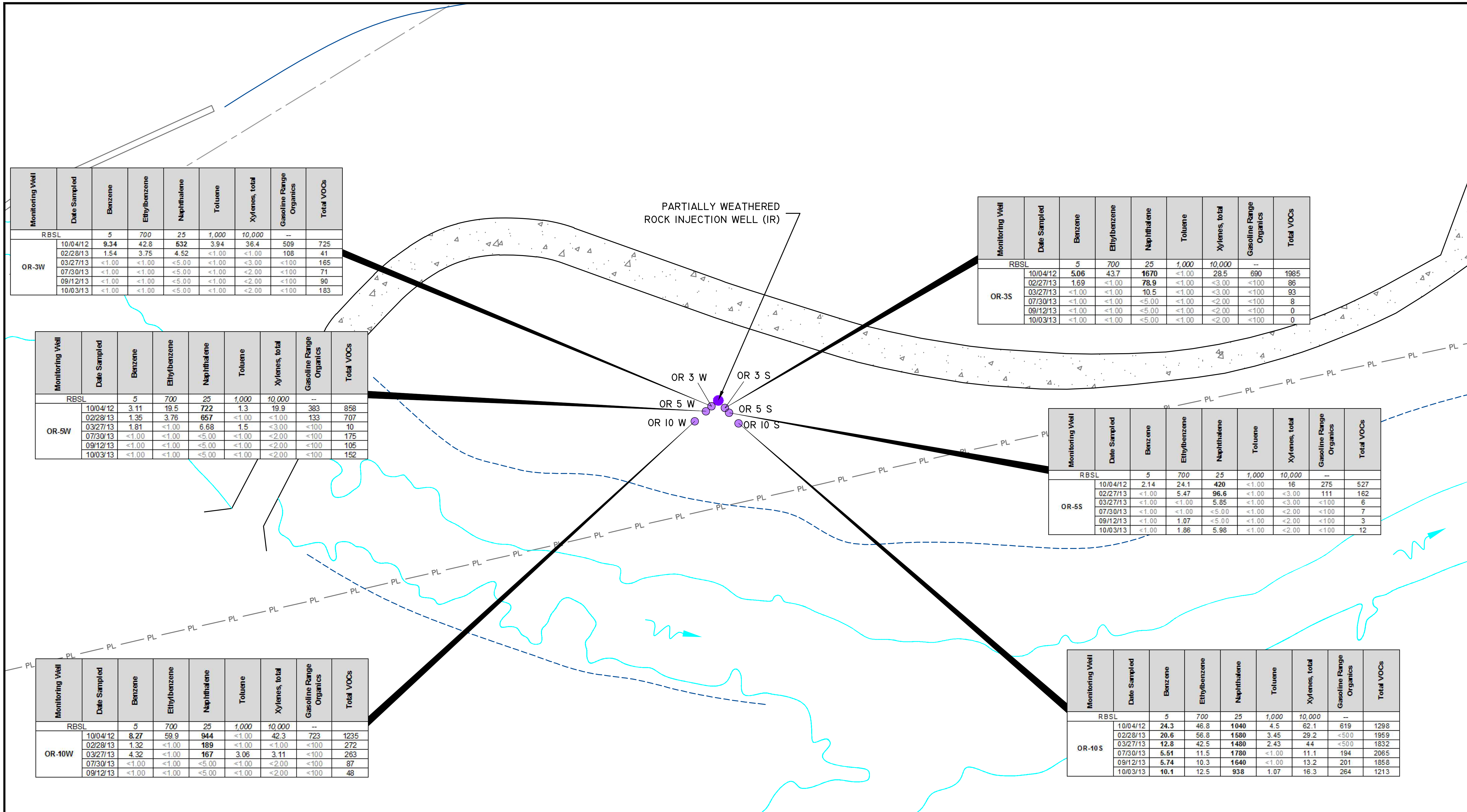
— PL —— PL — POWER LINE

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE: HISTORIC PAH PERFORMANCE MONITORING RESULTS
SHALLOW WELLS - PILOT AREA
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 30'		FIGURE. NO.: FIGURE 20



Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OR-3W	10/04/12	**9.34**	42.8	**532**	3.94	36.4	509	725
	02/28/13	1.54	3.75	4.52	<1.00	<1.00	108	41
	03/27/13	<1.00	<1.00	<5.00	<1.00	<3.00	<100	165
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	71
	09/12/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	90
	10/03/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	183

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OR-5W	10/04/12	3.11	19.5	**722**	1.3	19.9	383	858
	02/28/13	1.35	3.76	**657**	<1.00	<1.00	133	707
	03/27/13	1.81	<1.00	6.68	1.5	<3.00	<100	10
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	175
	09/12/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	105
	10/03/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	152

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OR-10W	10/04/12	**8.27**	59.9	**944**	<1.00	42.3	723	1235
	02/28/13	1.32	<1.00	**189**	<1.00	<1.00	<100	272
	03/27/13	4.32	<1.00	**167**	3.06	3.11	<100	263
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	87
	09/12/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	48

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OR-3S	10/04/12	**5.06**	43.7	**1670**	<1.00	28.5	690	1985
	02/27/13	1.69	<1.00	**78.9**	<1.00	<3.00	<100	86
	03/27/13	<1.00	<1.00	10.5	<1.00	<3.00	<100	93
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	8
	09/12/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	0
	10/03/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	0

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OR-5S	10/04/12	2.14	24.1	**420**	<1.00	16	275	527
	02/27/13	<1.00	5.47	**96.6**	<1.00	<3.00	111	162
	03/27/13	<1.00	<1.00	5.85	<1.00	<3.00	<100	6
	07/30/13	<1.00	<1.00	<5.00	<1.00	<2.00	<100	7
	09/12/13	<1.00	1.07	<5.00	<1.00	<2.00	<100	3
	10/03/13	<1.00	1.86	5.98	<1.00	<2.00	<100	12

Monitoring Well	Date Sampled	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylenes, total	Gasoline Range Organics	Total VOCs
RBSL		*5*	*700*	*25*	*1,000*	*10,000*	--	
OR-10S	10/04/12	**24.3**	46.8	**1040**	4.5	62.1	619	1298
	02/28/13	**20.6**	56.8	**1580**	3.45	29.2	<500	1959
	03/27/13	**12.8**	42.5	**1480**	2.43	44	<500	1832
	07/30/13	**5.51**	11.5	**1780**	<1.00	11.1	194	2065
	09/12/13	**5.74**	10.3	**1640**	<1.00	13.2	201	1858
	10/03/13	**10.1**	12.5	**938**	1.07	16.3	264	1213

LEGEND:

IR — PARTIALLY WEATHERED ROCK INJECTION WELL

OR 10 — PARTIALLY WEATHERED ROCK OBSERVATION WELL / DISTANCE IN FEET FROM INJECTION POINT / DIRECTION FROM INJECTION POINT

— PL —— PL — POWER LINE

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

CLIENT: DUKE ENERGY

TITLE: VOC PERFORMANCE MONITORING RESULTS
DEEP WELLS - PILOT AREA
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021	
CHK: ALA	DATE: 10/29/2013	DWG NO. NA	
SCALE: 0' 30'		FIGURE. NO.: FIGURE 21	

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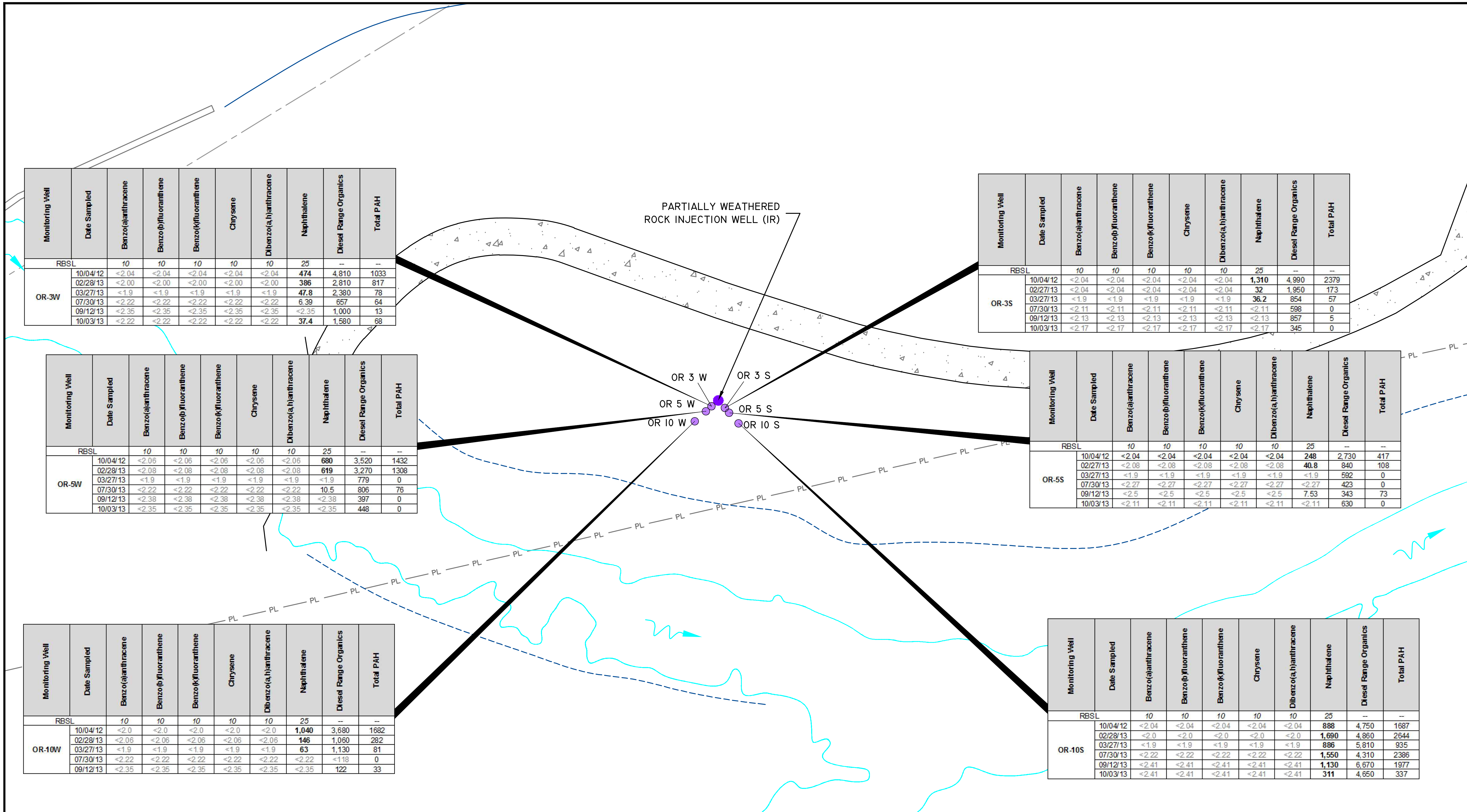

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OR-3W	10/04/12	<2.04	<2.04	<2.04	<2.04	<2.04	**474**	4,810	1033
	02/28/13	<2.00	<2.00	<2.00	<2.00	<2.00	**386**	2,810	817
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	**47.8**	2,380	78
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	6.39	657	64
	09/12/13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	1,000	13
	10/03/13	<2.22	<2.22	<2.22	<2.22	<2.22	**37.4**	1,580	68

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OR-3S	10/04/12	<2.04	<2.04	<2.04	<2.04	<2.04	**1,310**	4,990	2379
	02/27/13	<2.04	<2.04	<2.04	<2.04	<2.04	**32**	1,950	173
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	**36.2**	854	57
	07/30/13	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	598	0
	09/12/13	<2.13	<2.13	<2.13	<2.13	<2.13	<2.13	857	5
	10/03/13	<2.17	<2.17	<2.17	<2.17	<2.17	<2.17	345	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OR-5W	10/04/12	<2.06	<2.06	<2.06	<2.06	<2.06	**680**	3,520	1432
	02/28/13	<2.08	<2.08	<2.08	<2.08	<2.08	**619**	3,270	1308
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	779	0
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	10.5	806	76
	09/12/13	<2.38	<2.38	<2.38	<2.38	<2.38	<2.38	397	0
	10/03/13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	448	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OR-5S	10/04/12	<2.04	<2.04	<2.04	<2.04	<2.04	**248**	2,730	417
	02/27/13	<2.08	<2.08	<2.08	<2.08	<2.08	**40.8**	840	108
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	592	0
	07/30/13	<2.27	<2.27	<2.27	<2.27	<2.27	<2.27	423	0
	09/12/13	<2.5	<2.5	<2.5	<2.5	<2.5	7.53	343	73
	10/03/13	<2.11	<2.11	<2.11	<2.11	<2.11	<2.11	630	0

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OR-10W	10/04/12	<2.0	<2.0	<2.0	<2.0	<2.0	**1,040**	3,680	1682
	02/28/13	<2.06	<2.06	<2.06	<2.06	<2.06	**146**	1,060	282
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	**63**	1,130	81
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	<2.22	<118	0
	09/12/13	<2.35	<2.35	<2.35	<2.35	<2.35	<2.35	122	33

Monitoring Well	Date Sampled	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Naphthalene	Diesel Range Organics	Total PAH
RBSL		*10*	*10*	*10*	*10*	*10*	*25*	--	--
OR-10S	10/04/12	<2.04	<2.04	<2.04	<2.04	<2.04	**888**	4,750	1687
	02/28/13	<2.0	<2.0	<2.0	<2.0	<2.0	**1,690**	4,860	2644
	03/27/13	<1.9	<1.9	<1.9	<1.9	<1.9	**886**	5,810	935
	07/30/13	<2.22	<2.22	<2.22	<2.22	<2.22	**1,550**	4,310	2386
	09/12/13	<2.41	<2.41	<2.41	<2.41	<2.41	**1,130**	6,670	1977
	10/03/13	<2.41	<2.41	<2.41	<2.41	<2.41	**311**	4,650	337

LEGEND:

IR — PARTIALLY WEATHERED ROCK INJECTION WELL

OR 10 — PARTIALLY WEATHERED ROCK OBSERVATION WELL / DISTANCE IN FEET FROM INJECTION POINT / DIRECTION FROM INJECTION POINT

— PL —— PL — POWER LINE

AMEC Environment & Infrastructure, Inc.
9725 Cogdill Road
Knoxville, Tennessee 37932

amec

CLIENT: DUKE ENERGY

TITLE: PAH PERFORMANCE MONITORING RESULTS
DEEP WELLS - PILOT AREA
DUKE ENERGY PINE STREET MGP SITE
SPARTANBURG, SOUTH CAROLINA

DR: APT	REV: WPT	PROJ. NO.: 6228-12-0021
CHK: ALA	DATE: 10/29/2013	DWG NO. NA
SCALE: 0' 30'		FIGURE. NO.: FIGURE 22

P:\CADD\Projects\6228\6228120021 Duke Spartanburg SC\F 00 - 00 Tag Maps.dwg Nov. 13, 2013 william.wiers